THE EFFECTS OF AN EARLY INTERVENTION STRATEGY ON THE COUNTING, NUMBER IDENTIFICATION AND INHIBITORY CONTROL OF CHILDREN IN THEIR FIRST YEAR OF SCHOOL.

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Abstract

BACKGROUND: Poor counting and number identification in early childhood adulthood is associated with a wide range of negative adult outcomes. Despite the large amount of research showing a relationship between mathematics and inhibitory control, no intervention studies were found that included inhibition training as part of the numeracy instruction strategy. Therefore, the aim of this study was to assess the effectiveness of an audio taped counting and number identification intervention (Taped Numbers) and inhibitory control training (Inhibition Feedback) on counting and number identification in Aotearoa/New Zealand children in their first year of school.

METHOD: This study employed an across participants multiple baseline design. Participants were six children in their first year of school from a primary school in Christchurch, Aotearoa/New Zealand who were nominated by their teacher as likely to benefit from a counting and number identification intervention. Taped Numbers used an audio-delivered task-based feedback strategy and Inhibition Feedback used an instructor-delivered task-based feedback strategy.

RESULTS: Visual analysis of the data revealed that the Taped Numbers component of the intervention was moderately effective with two out of four replications for counting and three out of five replications for number identification. Extended Line Celeraton (ECL) analysis indicated large effect sizes for participants that made gains.

DISCUSSION: Although both Taped Numbers and Inhibition Feedback were effective, no relationship could be established between gains in inhibitory control and gains in counting and number identification. The results are also discussed in relation to the current literature on counting and number identification interventions in early primary school. The practical implications of the findings are discussed as are recommendations for future research.

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Abbreviations

ECL……………Extended Celeration Line

OECD…………Organization for Economic Cooperation and Development

TIMMS………..Trends in International Mathematics and Science Study

SES…………….Socio-Economic Status

NEMP…………National Education monitoring Project

TEMA…………Test of Early Mathematics Achievement

Chapter 1

Introduction to Numeracy

Numeracy

The Oxford Dictionary (2013) defines ‘numeracy’ as “the ability to understand and work with numbers.” Barwell (2004) expands on this, suggesting that unlike the term ‘mathematics’, which refers to abstract manipulation of numbers, ‘numeracy’ refers to an ability to work with numbers concretely. The Organization for Economic Co-operation and Development (OECD; 2009a) definition, also adopted by National Numeracy (2013), is a combination of these factors, defining numeracy as mathematics which is practical in everyday life. Similarly, in Aotearoa/New Zealand, The Ministry of Education defines being numerate as having the skill and inclination to use mathematics effectively at home, at work, and in the community (Ministry of Education, 2014). It is important to recognize that numeracy is not discrete, but rather a complex, multi-dimensional construct. Numeracy begins at a young age, and includes such skills as counting and identifying numbers.

Importance of Numeracy

Numeracy has historically been underestimated as a contributor to positive adult outcomes. This is perhaps surprising considering the quantity of everyday activities involving mathematics. Patton, Cronin, Bassett and Koppel (1997) identified many everyday activities which included mathematics across a range of settings including education, employment, home/family, leisure, health, interpersonal relationships and community involvement. For example most adults will need to use money on a daily basis for buying groceries, petrol and other goods. Another example is the need for sufficient mathematics to be able to understand time and be able to interpret clocks. It is less surprising then that adults with poor numeracy are more likely to have disadvantageous adult outcomes, even worse than adults with poor literacy (Bynner & Parsons, 1997; Parsons & Bynner, 2005). Two major areas of life that are substantially impacted by an individual's numeracy are their academic achievement and employment.

Children with poor numeracy tend to underachieve in school, often leaving earlier and without a formal qualification (Bynner & Parsons, 1997). Preschool numeracy has been shown to be a strong predictor of later success in mathematics (Claessens, Duncan & Engel, 2009; Duncan et al., 2007). In fact, there appears to be a stronger correlation between early mathematics and later mathematics than for any other subject (Stevenson & Newman, 1986). Furthermore, early achievement in mathematics also predicts later achievement in literacy more than early literacy predicts later mathematics, although the mechanisms through which this occurs are not clear (Claessens et al., 2009; Duncan et al., 2007).

After struggling at school, many adults with poor numeracy have greater difficulty finding and maintaining employment (Bynner & Parsons, 1997). This finding is congruent with the study by Durrani and Tariq (2012) which found that almost half the companies which responded to their survey tested for numeracy prior to employing graduates. When individuals with poor numeracy found employment they were typically jobs providing lower income and fewer opportunities for promotion (Bynner & Parsons, 1997).

The Development of Numeracy

The complex, multidimensional nature of numeracy is also evident when conceptualized along a developmental trajectory. Most children begin to develop a range of numeracy skills in infancy (Mix, Huttenlocher & Levine, 2002; Wynn, 1998; Sophian, 1998). These skills develop in parallel with each other and alongside a range of psychological constructs (Claessens et al., 2009). Contemporary evidence-based theories suggest that these interrelated skills interact in complex ways with environmental factors, including informal and formal instruction, to develop more advanced skills, although the exact processes of interaction remain elusive (Claessens et al., 2009). To understand the complex nature of numeracy development, the broad developmental trajectory of counting is considered as an example.

The ability to count is already developing soon after birth, as demonstrated by very young children who rapidly enumerate small sets of up to three, a process called subitizing (Sophian, 1998). Infants as young as five months have demonstrated an understanding of three major components of counting: the one-to-one principle, cardinality and the stable order principle, however they are unable to correctly apply all three principles simultaneously (Gelman & Galliste, 1978; Sophian, 1998). At around the age of two years, most children begin verbally counting objects (Fuson, 1992). Between the ages of 4½ and 5 most middle class American children were able to count to 20, with a few errors at 13 and above (Fuson, 1992). Despite evidence to suggest that there is a common pathway of numeracy development, individuals vary considerably (Fuson, 1992). Counting has been identified as an important foundational skill for the development of more advanced mathematics skills (Baroody, 1992; Clements & Sarama, 2009), particularly for learning efficient computation skills (Baroody, 1987; Kroesbergen, Van Luit, Van Lieshout, Van Loosbroek & Van de Rijt, 2009). For example, the first addition strategy that many children learn is counting each number out on a different hand and then counting the combined fingers from both hands to obtain the sum (Baroody, 1987). As they learn more efficient counting strategies they shift to counting up from one number to the total by a number of counts equal to the second number, for example in the addition '2+3' they start from two and count up "three, four, five" (Baroody, 1987). These, and other strategies, require accurate counting to be effective.

During the early development of counting skills in pre-schoolers several executive functions also begin to develop (Carlson, 2010). Several of these have been theorized to impact on the development of numeracy, including working memory (Ashcraft, Kirk & Hopko, 1998; Epsy et al., 2004) and inhibitory control (Blair & Razza, 2007; Epsy et al., 2004). Working memory is suspected of setting the limit for how much mathematical information can be maintained during multistep problems (Ashcraft et al., 1998). Inhibitory control has been implicated in numeracy development through the theory that it allows children to adopt alternate strategies when ineffective ones are being employed, such that children who have poor inhibitory control struggle to progress on multi-step tasks (Blair & Razza, 2007; Epsy et al., 2004). For example, when counting, children need to inhibit the ineffective response that is the current number to choose the correct number in the sequence. Importantly, evidence increasingly suggests that there is a dynamic and bidirectional relationship in the development of mathematics and these executive functions (Welsh, Nix, Blair, Bierman & Nelson, 2010; Van der Ven, Kroesbergen, Boom & Leseman, 2012). In light of the increasing evidence to support a correlation between executive functions and mathematics achievement a number of researchers have called for greater recognition of the relationship between these two areas in future research (Blair and Razza, 2007; Clark, Pritchard & Woodward, 2010; Cragg & Gilmore, 2014).

Mathematics Education in Aotearoa/New Zealand

Mathematics is appropriately considered an important subject within the national Aotearoa/New Zealand curriculum. Te Whāriki, the Aotearoa/New Zealand preschool curriculum, includes mathematics along the other major academic subjects (Ministry of Education, 1996). The Aotearoa/New Zealand primary school curriculum includes, from level one, a wide range of mathematical skills including aspects of number, algebra, geometry, measurement and statistics (Ministry of Education, 2007). Mathematics continues to be a core component of the curriculum throughout high school until Year 12 at which point mathematics diverges into two independent subjects: statistics and calculus whilst simultaneously becoming optional. Given the emphasis placed on mathematics within the national Aotearoa/New Zealand curriculum from the early years, a high level of mathematics achievement would be expected of Aotearoa/New Zealand children.

Mathematics Achievement in Aotearoa/New Zealand

To gauge the effectiveness of numeracy education in Aotearoa/New Zealand, international studies comparing the achievement of students across many countries are considered. The Trends in International Mathematics and Science Study (TIMMS; Mullis, Martin, Foy & Arora, 2011) is conducted every four years and aims to compare student achievement between, most recently, 65 countries. The TIMSS Year 5 mathematics assessment is designed to measure both mathematics content (number, geometry and data display) and cognitive processes (knowing, applying and reasoning). Each domain is examined with approximately 30 multiple choice items and 30 constructed answers. The most recent results, published in December 2012, revealed reduced mathematics achievement for Year 5 Aotearoa/New Zealand children, who achieved a scaled score of 486 (2.6) compared to the TIMSS scaled average of 500. This is a lower score than any other developed country. Furthermore, this is the lowest achieved by Aotearoa/New Zealand in that age group since 1996 (2007 – 492; 2003 – 493; 1995 – 469). These results indicate the possibility of new issues in mathematics instructions in the early years.

Another indicator of potential problems was reported by the 'National Education Monitoring Project' (NEMP; 2009), which found that a disproportionate number of Māori and Pasifika children achieve poorly in mathematics, with Year 4 Māori children scoring a mean of .45 standard deviation lower on mathematics than their Pākehā peers. Pasifika mean scores of mathematics were appreciably lower than both Māori and Pākehā (Ministry of Education, 2008). One possible contributing factor to the lower achievement reported in these two studies is associated with lower enrolments in early childhood education and/or children entering school with poor numeracy skills.

Early childhood education has been shown to have positive effects on school readiness, including numeracy (Magnuson & Waldfogel, 2005). Fewer Māori and Pasifika children starting primary school had attended early childhood education at 90.9% and 86.8% respectively compared to 98% of Pākehā children (Education Counts, 2013). This suggests that a disproportionate number of Māori and Pasifika enter primary school with a disadvantage in school readiness. Considering the strong relationship between early achievement and later achievement (Claessens et al., 2009), the reduced enrolment of Māori and Pasifika children in early childhood education programmes may contribute to the disproportionate number of Māori and Pasifika who achieve poorly in mathematics.

There have been many studies that have shown that children from low socio-economic status (SES) families perform worse than their peers in a number of mathematics tasks including counting and number identification (Dyson, Jordan & Glutting, 2011; Jordan, Kaplan, Olah & Lucuniak, 2006). Evidence indicates that a possible reason that children from low SES families underachieve is differences in environmental support for learning (Marie, Fergusson & Boden, 2008). Māori and Pasifika are more likely to come from low SES families (Chapple, 2000). Consequently, children from low socio-economic families are often the focus of mathematics interventions (Jordan et al., 2006; Jordan, Levine, & Huttenlocher, 1994; Seigler & Ramani, 2009).

Cultural differences may play a significant role in the mathematics achievement discrepancy between Māori and Pasifika and Pākehā. Western approaches to knowledge such as rationalism and decontextualizing are antithetical to Māori culture (Ministry of Māori Development, 1993). That is, mathematics pedagogy in many schools may not reflect Māori culture and this may contribute to low numeracy development in the early years of school.

Early Intervention

Current evidence indicates that early interventions are the most effective for altering the developmental trajectory of children struggling with mathematics (Barbaresi, 2011; Childers Jr & LaRosa, 2011). This is partly because numeracy begins developing at a young age and more advanced skills build on these foundational skills. If children do not effectively learn these early numeracy skills then they are unlikely to learn more advanced skills. Early numeracy skills that are appropriate for early interventions include counting and number identification as they are strong predictors of later skill in mathematics (Baroody, 1992; Clements & Sarama, 2009). Intervention strategies that aim to improve mathematics should therefore focus on foundational numeracy skills of young children.

The benefits of early intervention are not for the child and invested parties alone. Financial costs associated with low numeracy are high and early intervention can dramatically reduce this. For example, it has been estimated that in the UK alone an early intervention for numeracy could result of a lifetime savings of £1798.1 million (Every Child a Chance Trust, 2009). An effective early intervention strategy for numeracy has the potential to improve outcomes for children who struggle with learning mathematics and to reduce national costs associated with these difficulties.

Numeracy is a complex, multi-dimensional construct that includes skills such as number identification and counting. Numeracy skills develop along a complex trajectory, with skills such as counting and number identification foundational for more advanced mathematics (Purpura, Baroody & Lonigan, 2013). The trajectory of skills such as counting is influenced in part through executive functions which develop in parallel, although the nature of the interactions remains unknown. Children who begin school with poor counting and number identification skills are disadvantaged. Early intervention into these important skills may be useful in helping improve their learning during the first years of primary school.

Although Aotearoa/New Zealand has a strong emphasis on mathematics, from early childhood education through primary school and into high school, recent studies have shown that Aotearoa/New Zealand children perform worse than any other developed country in mathematics and that a disproportionate number of these children are Māori and Pasifika. The performance of Aotearoa/New Zealand children in international studies of mathematics achievement and the poor outcomes associated with poor mathematics in early childhood indicate a strong need for an effective early intervention that can influence the developmental trajectory of Aotearoa/New Zealand children who are struggling to learn mathematics.

Chapter 2

Literature Review

Interventions for Early Number Skills

In accord with the evidence that suggests early intervention as the appropriate strategy for numeracy, a search was conducted to identify relevant intervention studies. Ten counting and/or number identification interventions that targeted pre-schoolers, kindergarteners or early primary school children were identified from the literature search. Studies were excluded if they did not measure the numeracy skill of the child, for example if they measured parent perception of their child's numeracy skill. Studies were also excluded if the instruction did not occur in English, with the exception of the intervention in Dutch by Toll and van Luit (2013) because the similarities between the two languages is high for the identification of numbers between zero and 20 and for counting from one to 20.

Young-Loveridge (2004) investigated the effectiveness of an intervention to improve the numeracy of first grade students in a primary school. Participants were first grade students recruited from low socio-economic schools in Aotearoa/New Zealand and who had performed poorly on a measure of numeracy. Within each participating school the participants were assigned to either the intervention condition (n = 23) or the control (n = 83). The intervention employed board games and mathematics story books. In small groups, participants were engaged by a specialist teacher with number-oriented stories and games for 30 minutes each weekday for seven weeks (for a total of 17.5 hours). Task-based interviews with the children were used as a measure of numeracy and included counting, pattern recognition, enumeration, numeral recognition and addition and subtraction. The difficulty of the tasks was increased for the post-test measure. According to the author, this study demonstrated that playing number games and reading number stories and rhymes with a specialist teacher is effective in improving numeracy in early primary school children.

Arnold, Fisher, Doctoroff and Dobbs (2002) aimed to promote children's counting and other emerging mathematic skills by including math-related activities into the classroom routine. A pool of 85 activities were available for the teachers to select for each session and included books, music, games, discussion and group projects. To assess the effect of this intervention strategy, the study employed a randomized control trial with 112 participants recruited from Headstart schools in the United States. The duration of each intervention session was at the discretion of the classroom teacher and occurred every weekday for six weeks. Mathematics skill was measured pre-intervention and post-intervention using the Test of Early Mathematics Achievement 2 (TEMA-2) which assesses counting and other early numeracy skills in preschool children. The authors report a mean benefit in counting for the experimental group from counting to 13 to counting to 18.

Dyson et al. (2011) conducted a study which aimed to assess the effectiveness of a number sense intervention for kindergarteners from low-income families. Employing a randomized controlled trial, the study recruited 107 kindergarteners, with a mean age of 5.5 years, at risk of mathematics difficulties from kindergartens in the United States. Participants were randomly assigned to either the number sense group (n = 42) or the control group (n = 65). The intervention consisted of scripted lessons administered to small groups of approximately four participants over three weekly half hour sessions for eight weeks (for a total of 12 hours). The lessons focused on the relationship between language and mathematics and were individually tailored throughout the intervention based on informal assessments. Participants were measured pre-intervention, immediately post-intervention and at six-week post-intervention using the Number Sense Brief, a measure that includes a variety of tasks to measure early numeracy including counting and number identification. The authors report mean gains in counting from counting to five to counting to six and mean gains in number identification from recognizing three numbers to recognizing six numbers.

The aim of the study by Jordan, Glutting, Dyson, Hassinger-Das and Irwin (2012) was to assess the effectiveness of an intervention targeting number sense in kindergarteners at risk for mathematics difficulties. The intervention consisted scripted lessons and occurred over three weekly half hour sessions for eight weeks (for a total of 12 hours). The study used a randomized controlled trial in which 128 kindergarteners from five low-income schools in the United States were randomly assigned to one of three groups: number sense (n = 42), language control (n = 42) and business-as-usual control (n = 44). Early numeracy was measured using the Number Sense Brief at pre-intervention, post-intervention and eight-weeks delayed post-intervention. Participants made mean gains in counting from counting to six to counting to eight and mean gains in number identification from recognizing two numbers to recognizing six numbers.

Toll and van Luit (2013) assessed the effectiveness of an intervention for a wide range of numeracy skills including counting and number identification. Participants for this randomized control trial were recruited from six primary schools in the Netherlands and had a mean age of 63 months (SD = 4.37). The intervention took place in groups of 3-4 and occurred in two weekly half hour sessions for eight weeks (a total instruction time of eight hours). Participants were measured on the standardized Early Numeracy Test – Revised which includes verbal counting and number identification and the authors reported strong effects for this measure.

Seigler and Ramani (2009) assessed the effectiveness of linear board games in improving the ability of young children to count and identify numbers. The study used a randomized control trial wherein participants were 88 pre-schoolers from Head Start schools in the United States who were randomly assigned to either the linear board game condition (n = 30), circular board game condition (n=29) or the numerical control condition (n=29). Participants in the board game conditions played a linear numerical board game during five

15-20 min sessions over a three week period (total instruction time of approximately 1 hour and 20 minutes). Participants were measured pre- and post- intervention on counting and number identification. Siegler and Ramani (2009) suggest that results support linear board games – but not circular ones – as effective tools for increasing preschoolers' number identification with mean gains from recognizing six numbers to recognizing seven numbers. They also contended that the lack of gains in the counting measure were likely the result of a ceiling effect as pre-intervention measures were approaching maximum.

The aim of the study by Whyte and Bull (2008) was to establish if linear board games could be effective in allowing children between the ages of 3 and 5 to produce a linear representation of numbers and simultaneously increase their counting, number identification and magnitude estimation. The study utilized a randomized controlled experimental design, recruiting 45 preschoolers from nursery classes in Scotland and randomly assigning them to one of three conditions: linear board game (n = 16), non-linear board game (n = 16) and linear colour board game (n = 13). The intervention took place in four sessions of approximately half an hour each across four weeks (a total instruction time of two hours). The study recorded pre-and post- intervention scores of counting using the highest correct counting sequence when counting an array of small objects and number identification using worksheets with number pairs on it for which a point was awarded for a correct identification of a numeral. Based on these results, Whyte and Bull (2008) conclude that linear board games increase numeracy skills in pre-schoolers.

Ramani, Siegler and Hitti (2012) aimed to establish whether a small group board game intervention would be effective in improving the early numeracy of preschoolers. The randomized controlled trial study recruited 62 preschoolers, ranging in age from 3.6-5.7 years of age, from Head Start preschools in the United States. Participants in the experimental group played a board game in small groups of two to three, for four sessions of 25 minutes over 3- to 4- weeks (for a total instruction time of approximately two hours). Participants were measured pre- and post- intervention on counting and number identification. Counting was measured as the highest correct count when each child was asked to verbally count from 1 to 10. Number identification was measured by asking each child to identify each number from 1 to 10 from a shuffled deck of cards, each with a single number on it. Ramani et al. (2012) report that children in the study made no improvements in counting and made a mean improvement from identifying 6.3 numbers to recognizing 7.3 numbers.

Warren and deVries (2009) conducted a study with the aim of assessing the effectiveness of a numeracy intervention strategy for aboriginal children. To achieve this they recruited 125 children with a mean age of 4 years and 11 months from four Australian classrooms. Their intervention strategy took place instead of the regular mathematics curriculum and lasted for the entire school year. A wide range of instructional techniques were used including number games but more specific details were not described. Both counting and number identification were measured with the School Entry Number Assessment which consists of a variety of tasks conducted in an interview. The authors report strong gains for the numeracy measure.

Krohn, Skinner, Fuller and Greear (2012) aimed to expand the literature by employing a taped intervention for number identification in general education kindergarteners. The study by Krohn et al. (2012) used an across participants multiple baseline design and recruited two boys and two girls from kindergartens in the United States who were nominated by their teacher to receive the intervention. The intervention took five weeks, with a 4 minute intervention each week on Monday, Wednesday and Friday. The intervention consisted of an audio tape which was played to the children in small groups. Five variations of an audio tape were made and each one was paired with a worksheet which had the numerals from 0-9 in a random order. The intervention began when a tone on the audio tape prompted the children to make an attempt at identifying the first number on the worksheet. After a 2 second delay the audio tape played a recording of the corresponding numeral. The child then repeated the correct response. After another 2 second delay the next trial would begin. This occurred for each numeral on the worksheet. The study measured the percentage of correctly identified numbers at the beginning of each session by asking participants to verbally identify the numerals from 0-9 which were printed on an assessment sheet in a random order. Five variations of the assessment sheet were used to prevent the children from memorizing numeral locations with a sheet being randomly selected at the start of each asessment. All four participants improved dramatically in their ability to identify numbers, all reaching and maintaining one-hundred percent accuracy. Krohn et al. (2012) suggested that whereas previous research found taped interventions effective for sight-word reading and math fact deficits in older elementary school children in special education, their results show that taped interventions can also be an effective tool for improving the number identification skills of kindergarteners in general education.

Table 1

Key elements of studies of early intervention in counting and number identification.

Citation; Location	**Participants [N, Mean age, selection]**	**Study Design (instructional strategy, maintenance, group vs individual)**	**Intensity**	**Numeracy Skills Measured**	**Effect Size**
Young-Loveridge (2004) *Aotearoa/New Zealand.*	N= 151. M_{age} = 63.6 months 48% European, 44% Māori Lowest 66% on numeracy screen	Randomized controlled trial. Number games. Maintenance measured. Small groups.	30 min each week day over 7 weeks Total = (17.5 hours)	Composite Numeracy Measure (including counting and number identification).	d = 1.99.
Arnold et al. (2002). *USA.*	N = 112. M_{age} = 52 months (SD = 7.32). Head start.	Randomized control trial. Brief curriculum change. Maintenance not measured. Whole class.	1 session daily for an undefined duration for 6 weeks.	TEMA-2.	d = 0.64.
Dyson et al. (2011) *United States.*	N= 56. M_{age} = 66 months (SD = 4.2) *Low income.*	Randomized controlled trial. Curriculum change. Maintenance measured. Small groups (~4)	Three 30min sessions per week over 8 weeks. Total = (12 hours)	Counting Number identification	d = .65 d = 1.65

Citation; Location	**Participants [N, Mean age, selection]**	**Study Design (instructional strategy, maintenance, group vs individual)**	**Intensity**	**Numeracy Skills Measured**	**Effect Size**
Jorda et al. (2012) *United States.*	N= 42. M_{age} =66 months (SD = 4) *Low income.*	Randomized controlled trial. Comprehensive variety. Maintenance measured. Small groups.	30min x 3days x 8 weeks Total = (12 hours)	Counting Number identification	d = .82 d = 2.3
Toll & van Luit (2013). *The Netherlands.*	N = 196. M_{age} = 63 months Dutch. <25th percentile.	Randomized control trial. Structured activities. Maintenance not measured. Small groups (3-4).	1 hour sessions 5 days a week for eight weeks. Total = (40h)	Early Numeracy Test Revised (ENTR).	d = 2.95
Siegler & Ramani (2009) *United States.*	N= 30. M_{age} = 56 months (SD = .52) *Headstart classrooms*.	Randomized Controlled Trial. Board game. Maintenance not measured. Small groups (~4)	Five 25-30 min sessions within 3 weeks. Total = (2.5 hours)	Counting Number identification	Ceiling effect. d = .47
Whyte & Bull (2008). *Scotland.*	N= 45. M_{age} = 46 months (SD = 4) *No additional criteria.*	Randomized controlled trial. Board game. Maintenance not measured. Small groups.	Four 25-30 min sessions over 6 weeks. Total = (2 hours)	Counting ability Number identification	Authors report a significant effect.

Citation; Location	**Participants [N, Mean age, selection]**	**Study Design (instructional strategy, maintenance, group vs individual)**	**Intensity**	**Numeracy Skills Measured**	**Effect Size**
Ramani et al. (2012) *United States.*	N= 62. M_{age} =52 months (SD = 6) *Headstart classrooms.*	Randomized controlled trial. Board game. Maintenance not measured. Small groups (2-3).	Four sessions of 25 mins over 3- to 4-weeks. Total = (2 hours)	Counting Number identification	d = n.s.* d = .35
Warren & deVries (2009). *Australia.*	N = 14. M_{age} = 59 months. *Aboriginal.*	Quasi-Experimental. Number Games. Maintenance: not measured. Classroom wide.	Curriculum modification over an academic year.	School Entry Number Assessment (SENA)	η^2 = 0.83.
Krohn et al. (2012) *United States.*	N = 4. Kindergarteners, *Referred by Teacher.*	Multiple baseline across participants. Feedback. Maintenance measured. Individual and small groups.	4 minutes 3 days a week for 5 weeks. Total = (1 hour)	Number identification	Highest Calibre

* Not signficant.

Summary

To summarise the effects of early interventions on early numeracy, effect sizes on counting and number identification were either taken from the respective study or calculated from available data using the procedures described in Thalheimer and Cook (2002) and are presented in Table 2.1. In the 10 studies there were a total of 712 participants. The children participating in these studies ranged in age from 46 months to 66 months and included kindergarten through the first year of primary school. The mean total instruction time for the interventions was approximately 11 hours and ranged from one hour to 40 hours (excluding Toll and van Luit (2013) and Warren and deVries (2009) as total instruction time could not be calculated for these studies).

Nine of the studies aimed to improve participant counting ability within their intervention (Arnold et al., 2002; Dyson et al., 2011; Dyson et al., 2012; Ramani et al., 2012; Siegler & Ramani, 2009; Toll & van Luit, 2013;Warren & deVries, 2009; Whyte & Bull, 2008; Young-Loveridge, 2004). A number of these studies did not record gains for counting independently (Arnold et al., 2002; Toll & van Luit, 2013; Warren & deVries, 2009; Whyte & Bull, 2013; Young-Loveridge, 2004), however those that did found strong effects. The effect size of gains in counting for the study by Dyson et al. (2011) were calculated at d= .65 after an eight week scripted lesson intervention not exclusively targeted at improving counting. Surprisingly, Ramani et al. (2012) did not find a significant gain in counting ability following a board game intervention.

Of the studies identified in the literature search, ten included number identification training within the intervention (Arnold et al., 2002; Dyson et al., 2011; Dyson et al., 2012; Krohn et al., 2012; Ramani et al., 2012; Siegler & Ramani, 2009; Toll & van Luit, 2013; Warren & deVries, 2009; Whyte & Bull, 2008; Young-Loveridge, 2004). Although a number of these studies did not record gains for number identification independently (Arnold et al., 2002; Toll & van Luit, 2013; Warren & deVries, 2009; Whyte & Bull, 2008; Young-Loveridge, 2004), those studies that did found strong effects. Dyson et al. (2011) found that scripted lessons over an eight week period included large gains in number identification (d = 1.65). Jordan et al. (2012) found an even larger effect size, d= 2.3, over the same amount of time. Ramani et al. (2009) found that a board game intervention improved participants' number identification to a moderate effect size of d=.75. Furthermore, an effectiveness study found a considerably lower effect size of d=.34 when the board game intervention was implemented in a real world setting (Ramani et al., 2012). An effect size for the gains in number identification of participants in the study by Siegler and Ramani (2009) was calculated at d=.47. The calculated effect size of gains in number identification of children in the study by Ramani et al. (2012) was d=.35. Lastly, Krohn et al. (2012) found that a one hour audio-taped intervention had a remarkable impact on number identification with participants reaching one hundred percent correct number identification after just a number of four minute sessions. By comparing these effect sizes and considering the intensity of the interventions the audio-taped intervention by Krohn et al. (2012) appears to be the most efficient method of achieving a high level of competence in numeral identification.

Six of the ten studies identified in the literature search used feedback about the task as an instructional tool (Dyson et al., 2011; Jordan et al., 2012; Krohn et al., 2012; Ramani et al., 2012; Siegler & Ramani, 2009). Dyson et al. (2011) provided feedback on each of the tasks in the intervention in the form of correction when errors were made. Jordan et al. (2012) also provided feedback on the task through error correction. Krohn et al. (2012) employed feedback on the task during the intervention by providing the correct answer through an audio-tape after both correct and incorrect responses with an opportunity for the children to correct themselves after the feedback. Participants in the study by Ramani et al. (2012) were provided with feedback about the self in the form of motivational praise and feedback on the task as a correction when they made an error. Siegler and Ramani (2009) provided feedback on the task through supplying the correct answer when errors were made and having each child repeat the correct response. Of the studies that used feedback on the task, two also included immediate opportunities for the children to employ the feedback (Krohn et al., 2012; Seigler & Ramani, 2009).

Four of the ten studies identified in the literature search described interventions that required training to implement (Arnold et al., 2002; Dyson et al., 2011; Jordan et al., 2012; Toll & van Luit, 2013). The study by Arnold et al. (2002) provided two hours of training to the classroom teachers prior to implementation of the intervention. The study by Dyson et al. (2011) recruited university students studying education who were provided with weekly training sessions throughout the intervention. The instructors in the study by Jordan et al. (2012) recruited university graduates with a degree in education in addition to five undergraduate students of education who received special training. Toll and van Luit (2013) selected individuals with a bachelor’s degree in education, special education or child psychology to implement the intervention and provided them each with four hours of training.

Of the ten studies identified in the literature search, eight employed randomized controlled trials (Arnold et al., 2002; Dyson et al., 2011; Jordan et al., 2012; Ramani et al., 2012; Seigler & Ramani, 2009; Toll & van Luit, 2013; Young-Loveridge, 2004). The study by Warren and deVries (2009) used a quasi-experimental design and the study by Krohn et al. (2012) used a single case research design.

Although a number of studies have shown large effects for improving counting and number identification in children in their first years of school there are a number of limitations that prevent these interventions from being suitable for Aotearoa/New Zealand children.

Limitations

For the sake of clarity is should be noted that existing literature incorrectly employs the terminology of ‘number identification’ to mean ‘numeral identification.’ A number is the abstract concept of a magnitude, whereas a numeral is the expression of that number. For example the magnitude of three is a number, but the symbol ‘3’ is a numeral. Studies that discuss ‘number identification’ are concerned with the skill of naming numerals. To remain consistent with previous studies the term ‘number identification’ will also be used throughout the present study.

Given the strong relationship between inhibitory control and mathematics ability (Blair & Razza, 2007; Bull & Scerif, 2010; Clark, Sheffield, Wiebe & Epsy, 2013; Espy et al., 2004; Kroesbergen et al., 2009), numeracy interventions should include components that target inhibitory control. For children struggling with early numeracy who have low inhibitory control, intervention strategies that do not include inhibitory control training are likely to have limited effectiveness. Consequently the effectiveness of all the interventions identified in the literature search are limited by not including inhibitory control training within their procedures. Future studies should include inhibitory control training to enhance the effectiveness of early numeracy training.

For feedback to be an effective instructional tool it must be provided on the task and the child must be given immediate opportunity to utilize the feedback (Baker, Gersten & Lee, 2002; Sadler, 1989). Despite this, only two of the intervention studies identified in the literature search met both of these criteria for effective feedback (Krohn et al., 2012; Seigler & Ramani, 2009). Future intervention studies should utilize the strong effects of feedback on the task by ensuring that children have an immediate opportunity to use the feedback when provided.

Interventions requiring special training to implement are less easily incorporated into school system because they require additional time from staff who are already have a heavy workload. Furthermore, training is often costly and many schools do not have the financial resources to train their staff in specialized interventions (OECD, 2009b). Four of the ten studies identified in the literature search trained the instructors how to implement the intervention limiting their practicality in schools where staff are already very busy (Arnold et al., 2002; Dyson et al., 2011; Jordan et al., 2012; Toll & van Luit, 2013). To increase the likelihood that an instructional strategy will be utilized by schools future interventions should aim to minimize the training required for implementation to improve the probability that schools will employ the intervention strategy.

The intervention by Toll and van Luit (2013) was implemented in Dutch. Language has been shown to impact the acquisition of mathematics skills in children (Fuson & Youngshim, 1992). Counting in English varies substantial from most other languages, particularly in the numbers from ten to twenty which are non-systematic in English: "eleven, twelve and thirteen" followed by "four-teen, fif-teen, etc" instead of following the system for the remaining numbers that has the tens value first. Although the differences between counting to 20 and recognizing numbers up to 20 in Dutch and English are minimal, effectiveness of the intervention cannot be assumed for English speaking children.

An important aspect of any intervention attempting to have practical value within the Aotearoa/New Zealand education system must consider the cost of the intervention strategy. As the cost of implementing an intervention is related to the intervention's intensity, reducing the intensity of an intervention, particularly if effect sizes can be maintained, is highly desirable. At least two of the studies identified in the literature search have a total instruction time of 40 hours or more (Toll & van Luit, 2013; Warren & deVries, 2009).

The studies by Toll and Van Luit (2012), Young-Loveridge (2004) and Warren and DeVries (2009) measured improvement in numeracy skills collectively in a single measure. By doing so, these studies limit the conclusions that can be drawn regarding the intervention’s effectiveness for each skill independently. Given that many children struggle with specific components of numeracy but not with others (Gersten, Jordan & Flojo, 2005), there is a need for increased research that measures numeracy skills independently. Future studies should seek to measure gains of different numeracy skills independently so that the effectiveness of intervention strategies can be identified for each skill specifically.

Of the intervention studies reviewed, only the study by Young-Loveridge (2004) was conducted within Aotearoa/New Zealand and its unique low-achieving demographic. Given that the demographic of children that struggle within the New Zealand education system contain a disproportionate number of Maori (Ministry of Education, 2008; NEMP; 2009), and that international studies are unlikely to include any Maori, the effectiveness of interventions studied internationally cannot be assumed for Aotearoa/New Zealand children.

All of the studies identified in the literature search except for Krohn et al. (2012) used between group designs. As group designs use means they are easily influenced by extreme values (Aron, Aron & Coups, 2009). Thereby a single participant who scores extremely high or extremely low on a measure has disproportionate influence on the interpretation of the results. These designs also do not provide information regarding how many children improved as result of the intervention.

Single case research allows the researcher to observe participant change on measures over time through repeated measurement which collectively provide trend and variance data for each participant. By including baselines in the design of this study each participant’s direction of change prior to the implementation of the intervention can be taken into account when analysing any effects. Repeated measures during the intervention phase provides the opportunity to observe the intervention effects over time allowing conclusions to be made regarding the rate at which intervention effects occur. Repeated measures during follow up are implemented because they allow for an analysis of trend and variability of any change since the intervention strategy ceased. Future research should be conducted using single case designs to allow for an analysis of trend and variability for each participant.

Executive Functions

Executive function refers collectively to the various skills required to control cognitive processing (Bukatko, 2008). Among the skills that are commonly recognized as existing with the executive functions are attention, planning, switching, working memory and inhibitory control. Attention shifting is the ability to switch cognitive processing between different tasks (Miyake et al., 2000) Working memory is the capacity to actively manipulate information in the conscious mind (Toll & van Luit, 2013). Inhibitory control is the capacity of an individual to inhibit irrelevant information from entering the working memory (Blair & Razza, 2007; Miyake et al., 2000). Each of these skills is a component of executive function and none of them are entirely independent of each other.

Common measures of inhibitory control include Stroop interference tasks and peg-tapping. Stroop interference tasks involve the selection of a stimulus whilst being present with a more dominant stimulus. For example, selecting small shapes in a picture which includes large shapes (Clark et al., 2013). Children need to inhibit the response of selecting the larger shapes so they can identify the smaller ones. The peg-tapping measure of inhibitory control requires the participant to tap a wooden dowel twice when the experimenter taps once and to tap once when the experiment taps twice. To do well at this task, children must inhibit the natural tendency to copy the experimenter. The internal reliability of the measure is approximately $\alpha = .82$ for preschool children (Diamond, Prevor, Callendar & Druin, 1997).

Blair and Razza (2007) aimed to examine the inter-correlations between inhibitory control, false belief understanding, effortful control and mathematics skills in kindergarteners. The study recruited 170 children between the ages of 3 years 9 months to 5 years 8 months (m = 5 years, 1 month) who were either below the poverty thresholds or were participating in the Head Start program. Inhibitory control was measured using the peg-tapping measure and mathematics was measured with a mathematics battery designed to assess early numeracy. The study found that skill in mathematics correlated with inhibitory control ($r = .44$), with false belief understanding ($r =.38$) and with effortful control ($r = .42$).

Espy et al. (2004) aimed to determine how empirically determined executive functions are related to mathematics proficiency in pre-schoolers. Participants in the study were 96 pre-schoolers aged between 2 and 5 years of age (m = 3.9) of which approximately one third were born preterm with low neurobiological risk. Participant's mathematic skills were measured with the TEMA 3. Participant's inhibitory control was measured as a composite of four tasks including a Stroop interference task, a task where the experimenter attempted to distract the child from pretending to be a statue, a task where the child was distracted from a desirable object for as long as possible, and a task wherein the child had to remember which cup, of two, a reward was hidden under whilst being distracted by the researcher counting to ten in an engaging manner. Results showed that early numeracy skill had a correlation of .55 with the inhibitory control.

Bull and Scerif (2010) also explored the relationship between executive functions and mathematic skills in children. They recruited 93 children from six primary schools in Scotland with a mean age of 7 years 4 months (SD = 3.8 months). Inhibitory control was measured through a Stroop interference task and numeracy was measured as a composite with the Group Mathematics Test. The study found that mathematics skill correlated with inhibitory control (r = .46). This result also provides support for the importance of the relationship between inhibitory control and early numeracy.

The aim of the study by Clark et al. (2013) was to examine the relationship between a variety of executive functions and mathematics skill. To this end they recruited 228 children with a mean age of 35 months who fell within the ‘normal’ developmental range to participate in their longitudinal study. When each participant turned three years of age their mathematics was measured using the TEMA and inhibitory control was measured using a Stroop interference task. Results indicate a moderate correlations between inhibitory control and mathematics (.30).

Kroesbergen et al. (2009) aimed to investigate the relationship between executive functions and counting. They recruited 115 Dutch children with a mean age of 72 months (*SD* = 4) to participate in their study. Participant counting was measured using the counting subtest of the Early Numeracy Test and their inhibitory control was measured using a Stroop interference task. These scores were correlated and showed a relationship between counting and inhibitory control (.22).

These studies show that inhibitory control is related to early numeracy skills including counting (Blair and Razza, 2007; Bull and Scerif, 2010; Clark et al., 2013; Espy et al., 2004; Kroesbergen, et al., 2009). For example a number of researchers have suggested that the theoretical rationale for the relationship between inhibitory control and counting is the requirement of the counter to inhibit previous responses whilst progressing along the numerical sequence (Clark et al., 2013; Noel, 2009)This relationship has led a number of researchers to call for the inclusion of executive function scaffolding in early mathematics education and interventions (Blair and Razza, 2007; Clark, Pritchard & Woodward, 2010).

Training Executive Function

There is a dearth of research on training executive functions. The research that does exist indicates that experience on tasks that require executive functions will increase the respective executive function. Dowsett and Livesey (2000) conducted a study with 51 preschoolers between the ages of three and five who had been identified as non-inhibitors. Participants were divided into three groups: control, practice and training. Participants in the control group received no exposure to inhibitory control tasks. Those in the practice group engaged in a basic rule-change task, wherein the participants had to adjust their response based on a changing rule but were not given explicit feedback. Participants in the training condition completed the same tasks as the practice group, but with explicit feedback about the task. Participants in control group made no gains, whereas those in both the practice and training groups made significant gains. Children in the training group made substantially greater gains than those in the practice group. The experimenters theorized that receiving feedback during practice on an inhibitory control task was responsible for the improved inhibitory control post-intervention.

Feedback

A meta-analysis synthesis of instructional research which evaluated the effectiveness of feedback concluded that instruction strategies that employed feedback contributed a substantial amount to learning in children (Hattie, 2009). However this claim needs to be taken cautiously as there are various types of feedback which vary dramatically in their impact on learning from having a strong positive impact to being detrimental to learning (Kluger & DeNisi, 1996). The four major types of feedback are ‘feedback on the task’, ‘feedback on the processing of the task’, ‘feedback about self-regulation’ and ‘feedback about the self’ (Hattie & Timperley, 2007). ‘Feedback on the task’ is feedback that helps the learner make sense of the difference between their attempt on a task and the goal of the task, ‘feedback on the processing’ is feedback that reflects the effectiveness of strategies used, ‘feedback on self-regulation’ provides information regarding the way in which a learner is using their own cognitive resources to tackle the task and ‘feedback about the self’ provides feedback regarding the self and is synonymous with personal praise. Of these, ‘feedback on the task’ is considered to be the most effective instructional tool (Hattie & Timperley, 2007). There is also evidence to indicate that the use of recorded feedback, such as computer delivered animated or voiced feedback delivered via audio-tape and headphones, are particularly effective for teaching children who are struggling learners of mathematics (Baker, Gersten & Lee, 2002). For feedback to be effective students must be aware of what the goal of the task is, become aware of how their success on a task matches the goal success on the task and then be given an opportunity to use this knowledge to make a better attempt at the task (Baker et al., 2002; Sadler, 1989).

Summary of Limitations

The intervention studies identified in the literature search were all limited in their application to Aotearoa/New Zealand children in various ways. These studies were either intensive (Toll & van Luit, 2013; Warren & deVries, 2009), did not have strong effect sizes (Arnold et al., 2002; Dyson et al., 2011; Siegler & Ramani, 2009; Ramani et al., 2012), did not use effective feedback strategies (Arnold et al., 2002; Dyson et al., 2011; Jordan et al., 2012; Ramani et al., 2012; Toll & van Luit, 2013; Whyte & Bull, 2008; Warren & deVries, 2009; Young-Loveridge, 2004), required specialized training to implement (Arnold et al., 2002; Dyson et al., 2011; Jordan et al., 2012; Toll & van Luit, 2013) and/or did not measure numeracy skills independently (Arnold et al., 2002; Toll & van Luit, 2013; Warren & deVries, 2009; Young-Loveridge, 2004). Furthermore, none of the studies incorporated inhibitory control training into their intervention procedures despite a strong relationship between inhibitory control and mathematics (Blair and Razza, 2007; Bull and Scerif, 2010; Clark et al., 2013; Espy et al., 2004; Kroesbergen, et al., 2009).

Overall Summary and Research Question

Both inhibitory control, counting and number identification contribute substantially to the development of mathematic skills in children. An early intervention strategy that is effective in developing these skills has the potential to improve the adult outcomes for Aotearoa/New Zealand children. By including feedback on tasks with immediate opportunity for utilizing the feedback. This study aims to assess the effectiveness of an audio-taped intervention and inhibitory control training on the counting and number identification of Aotearoa/New Zealand children in their first year of school.

Chapter 3

Method

Design and Rationale

This study employed an A (baseline), B (instructional intervention), with follow-up, across participants in a non-concurrent multiple baseline design (Bailey & Burch, 2002), to measure the effects of an audio taped intervention and inhibitory control training on the counting, number identification and inhibitory control of children in their first year of school. This study utilized this design so that participant slope and variability on counting, number identification and inhibitory control could be taken into consideration when analysing the effects of Taped Numbers and Inhibiton Feedback.

By implementing multiple baselines across participants the experimental control of this study was increased. The replication of effects across a number of participants increases confidence that any observed effects associated with the introduction of the intervention are attributable to the intervention and not to confounding factors external to the experiment, such as maturation (Gast, 2010).

Ethics

This study was approved by the University of Canterbury Educational Research Human Ethics Committee (Appendix B). To fulfil the requirements for ethical approval, participants and their respective parents, teachers, principals and board of trustees provided written informed consent prior to their involvement in the study. An approved information sheet detailing the study was provided to all relevant parties. Children were given the right to withdraw from the study at any time and have their data removed and destroyed. In line with this right, one participant was not included in the study after repeatedly declining to complete the screen. All reasonable endeavours were made to ensure child confidentiality including the use of synonyms and the storage of sensitive material in a secure location.

Setting

This study was conducted in a Decile 2, primary school in Christchurch, Aotearoa/New Zealand located in a lower socio-economic neighbourhood. There were four classrooms for children starting school and three of these were involved in the research. Individual experimental sessions took place at a small desk in the back of each child’s respective classroom away from the main teaching environment. During the experimental period, normal teaching of mathematics occurred on most days and consisted of approximately half an hour of instruction in either numeracy or basic statistics in accord with the Aotearoa/New Zealand Curriculum (Ministry of Education, 2007).

Recruitment and Participants

Potential participants were nominated by their teacher as likely to benefit from an intervention in counting and number identification. A number of inclusion and exclusion criteria were applied to children nominated by their teacher. Children with special education needs were excluded from the study as they already receive additional support. To ensure that all children would benefit from the instructional intervention, a screening test was conducted with each child to estimate their pre-study levels of counting, number identification and inhibitory control. There were two ways this could lead to exclusion from the study. Firstly, if a child obtained a score of 18 or above on the measure of counting *and* a score of 36 or above on the measure of number identification they were excluded from the study. For example, a child who scored 18 on counting *and* 37 on number identification would be excluded from the study, but a child who scored 20 on counting and 17 on number identification would not be excluded. When a child was excluded from the study they were thanked for their involvement and further participation in the study ceased. Three participants were excluded based on their scores from the screen. Five boys and two girls began the study, however one girl moved away prior to the completion of the study.

One child was identified by the school records as Samoan, one child identified as Māori and all other children were identified as European New Zealanders. Charlie had been at school for five months and could count to 9, could recognize 7 numbers, and made 8 correct tapping responses out of sixteen. Drew had been at school for six months and could count to 14, could recognize 9 numbers, and made 10 correct tapping responses out of sixteen. Sam had been at school for five months and could count to 10, could recognize 28 numbers, and made 9 correct tapping responses out of sixteen. Yvette had been at school for 1 month and could count to 10, could recognize 1 number, and made 5 correct tapping responses out of sixteen. Alex had been at school for 7 months and could count to 9, could recognize 9 numbers, and made 5 correct tapping responses out of sixteen. Harri had been at school for six months and could count to 20, could recognize 9 numbers, and made 15 correct tapping responses out of sixteen.

Materials and Measures

Table 2

List of Materials with a Description.

Material	Description
Number Identification Deck	A deck of 40 cards. These cards were 7cm x 5cm made from white cardboard. Each card contains a single number between 1 and 20 inclusive, with each number occurring twice.
Voice Recorder	Olympus Digital Voice Recorder DS-2.
MP3 Player	All audio was played from a Samsung GoGear 4GB MP3 player through earphones.
Earphones	Two variations of earphones were used. Initially participants used Dick Smith branded earphones, however they repeatedly fell out for some participants so they were replaced by Dick Smith Earhook Headphones (Figure 1).  *Figure 1*. Dick Smith Earhook Headphones *(image source: http://www.dicksmith.co.nz/headphones/dick-smith-earhook-headphones-dsnz-a2170)*

Material	**Description**
Number Identification Worksheet	Each worksheet had two parts: the top row consisted of 5 numbers, randomly selected, between 0 and 20. This top row was used for demonstration and practice purposes. The remainder of the table consists of eight rows of five numbers, which contained the numerals 0-20, repeated, for a total of 40 numerals. The order of the numerals was randomly allocated to their sequence using Microsoft Excel in sets of 20 such that all the numbers from 1 to 20 occurred once before repeating. Each worksheet has an audio playlist for the demonstration and practice component and an audio playlist for the intervention proper.
Number Identification Audio File	Five variants of an MP3 audio file for number identification were created. Each audio file contained 40 whole numbers between 0 and 20 in the following sequence: tone, one second delay, number, one second delay. The order of the numbers for each audio playlist matched that of one of the counting worksheets.
Number Identification Practice Audio File	Five variants of an MP3 audio file for practice on the number identification training were created. Each audio file contained 5 whole numbers between 0 and 20 in the same sequence as described above. Each variant matched the practice section of a number identification worksheet.

Material	Description
Counting Worksheet	Each worksheet had two parts: the top row consisted of five numbers, randomly selected, between 0 and 20. This top row was used for demonstration and practice purposes. The remainder of the table consists of eight rows of five numbers, which contained the numerals 0-18, repeated, for a total of 38 numerals. The order of the numerals was randomly allocated to their sequence using Microsoft Excel in sets of 19, such that all the numbers from 0 to 18 occurred once before repeating. Each worksheet has an audio file for the demonstration and practice component and an audio file for the intervention proper.
Counting Audio File	Five variants of an MP3 recording were created. Each recording contained 38 whole numbers between 0 and 18 in the following sequence: tone, two second delay, number, subsequent number, one second delay. The order of the numbers for each audio filed matched that of one of the counting worksheets.
Counting Practice Audio File	Five variants of an MP3 audio file for practice on the counting training were created. Each audio file contained 5 whole number pairs (n and n+1) between 0 and 18 in the same sequence as described above. Each variant matched the practice section of a counting worksheet.
Dowel	A 1cm x 15cm wooden dowel.

Material	Description
Colour die.	The colour die was a simple six sided die with a different colour on each side as shown in Figure 2.  *Figure 2. Six sided colour-sided die.*
Humpty Dumpty's Wall game®	Humpty Dumpty's Wall Game is a game published by Kiddie Kloud. Humpty Dumpty's Wall Game consists of 44 bricks which fit inside a 25cm x 25cm frame to form a wall upon which Humpty Dumpty sits.

Counting. Counting was measured during each session in all three phases. To identify changes in child counting throughout the study, counting was measured at the end of each session in a similar manner to that used by Ramani et al. (2012). Each child was given a single trial wherein they were asked to count to 20 from 1. The trial began when the voice recorder was set to record and the child was told to begin. The trial ended when the child counted aloud to 20 or ceased to continue their attempt for more than 10 seconds. After the conclusion of the session, the researcher listened to the response and recorded the highest number correctly counted to without error on a scoring sheet and a graph. A response was considered correct when the child verbalized the $n+1^{th}$ number in the sequence within 10 seconds. In the example response, "One, two, three, [6 second pause], 4 [no more responses]", the child was recorded as correctly counting to four. A response was considered incorrect when it took more than 10 seconds to verbalize the next number in sequence. For example, if a child said “one, two, three, four, five, [12 second pause], six” the first five responses would be scored correct but the sixth would be incorrect. An incorrect response was also recorded if the child said an out-of-sequence number. For example, if a child counted “one, two, three, four, five, six, seven, nine, ten, eleven”, the child would be recorded as correctly counting to seven. A single self-correction on this measure was allowed each session. A self-correction was considered a correct response when it was made within 3 seconds of an incorrect response. For example, “one, two, three, five, [2 seconds], no, wait, four, five, six [12 second pause]” would be recorded as correctly counting to six.

Number identification. Number identification was measured during each session in all three phases. Number identification was measured as number of correctly identified numbers from the number identification deck. To start the trial the child was invited to shuffle the cards on the desk. Once the deck was shuffled the voice recorder was set to record and the child was asked to pick any card out and verbally identify the number on it. The card was then placed horizontally in a discard box appropriately sized to avoid card mixing. This process continued until all the cards had been selected. Following the conclusion of the session, the child’s recorded responses were matched to the order of cards in the discard box and a score equal to the number of correct identifications was recorded on a scoring sheet. This measure is similar to that used in Purpura et al. (2013) except that it uses all the numbers between zero and twenty twice, instead of just nine numbers once.

Inhibitory control. To assess whether inhibitory control gains were made in the instructional intervention, the peg tapping measure of inhibitory control described in Diamond and Taylor (1996) and implemented in the study by Blair and Razza (2007) was utilized in this study. In this task, the child was asked to tap the wooden dowel once when the researcher tapped twice and to tap twice when the researcher tapped once. A response of one tap to a double tap within three seconds, or a double tap to a single tap within three seconds was considered correct. Any other response greater than or less than the appropriate response was considered incorrect as was a delay of over 3 seconds. The instructions were repeated once if the child responded incorrectly to the first trial. Sixteen trials were conducted during each session. Each trial was started with either a single tap or double tap at the researcher's discretion with eight single taps and eight double taps occurring each session. Trials were separated by a three second pause after each child response to mark the transition between trials and to allow the child one immediate self-correction. A self-correction was scored as correct if it was made immediately after the initial response. Only the first self-correction by a child each session was scored as correct, and subsequent self-corrections were recorded as errors. A single dowel was shared between the researcher and the child. This prevented the child from tapping before or during the instruction, and ensured that the child was listening to the experimenter. Tapping responses were recorded on a voice recorder. After each session the recording was listened to and an overall score out of 16 assigned and graphed by session.

Procedures

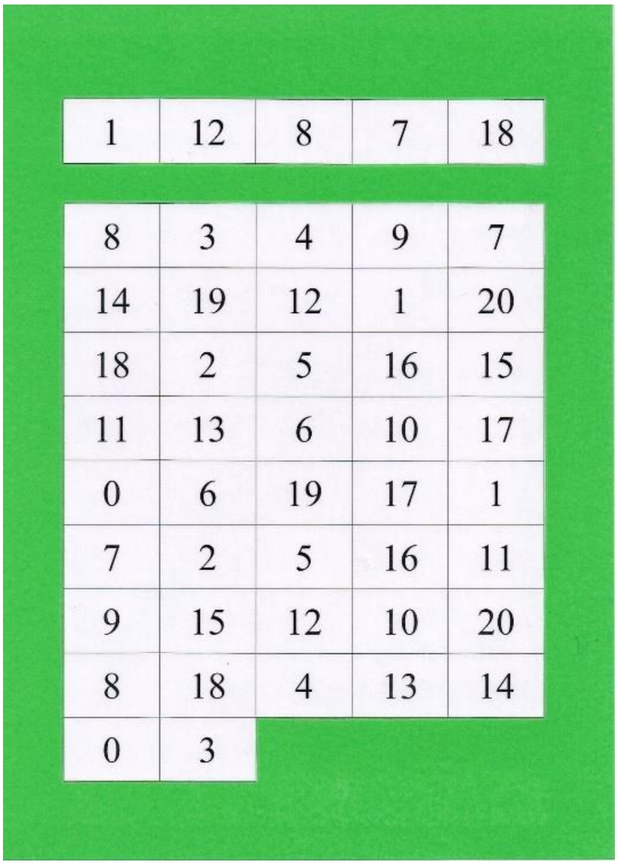
All sessions were conducted with individual children in a one-to-one situation with the researcher. The researcher entered the child's classroom at a time established with the classroom teacher. Each child was asked to join the researcher to help with his study. The child and researcher were seated at a desk opposite each other. Each session finished with verbal praise, e.g., "You did great today [child name]!", and a re-orientation to the classroom through questions such as "what are you going to do in class now?" Missed sessions were rescheduled.

Baseline Phase. Baseline sessions began with the researcher playing 'Humpty Dumpty's Wall Game®' with the child for 10 minutes. This game was selected because it is unlikely to have an impact on counting, number identification or inhibitory control. Following the game, measures of counting, number identification and inhibitory control were conducted. The screening session was considered as the first day of the baseline phase. After each measure the child was praised for their efforts but no feedback regarding their overall score was provided. The first two children to complete six baseline sessions moved into the intervention phase. The next child moved into the intervention phase at seven baseline sessions. Each subsequent participant had one more baseline session than the last. The number of baseline sessions followed the proceeding sequence for a multiple baseline design: 6, 6, 7, 8, 8, 9.

Figure 3. Humpty Dumpty's Wall Game. (image source: *mitzvahfamily.com*)

Intervention Phase. Instructional training in number identification, counting, and inhibitory control was given, with each instructional element incorporated in each session in the sequence listed above. All key instructional elements for the counting and number identification components were delivered by audio files on the MP3 player. Sessions lasted approximately 20 minutes and each child had between six and nine baseline sessions, ten intervention sessions and six follow-up sessions. Intervention sessions consisted of a series of tasks.

Number identification training. The first task of the session was instruction in number identification. The child rolled the six-sided colour-sided die to determine which number identification worksheet would be used for the session (Figure 4). Each colour matched a worksheet, except for red which was “roll again.” Both audio files signalled the start of the trial by making a tone, followed by a 2 second delay wherein the child made their best attempt at identifying the first number on the worksheet. Then the taped voice reads aloud the English word for the number followed by a pause to allow the child to repeat the number out loud. Another tone signalled the next trial.



1	12	8	7	18

8	3	4	9	7
14	19	12	1	20
18	2	5	16	15
11	13	6	10	17
0	6	19	17	1
7	2	5	16	11
9	15	12	10	20
8	18	4	13	14
0	3			

Figure 4. An example of a number identification worksheet.

Each session the number identification training task began with the verbal instructions modified from Krohn et al. (2012):

“Let’s play this game. When you hear a noise, say the number you see and then wait until you hear what the tape says to see if you got it right. Then, repeat the number after you hear the tape say it. What you want to do is try to beat the tape and say the number before you hear the answer. I’m going to show you how to do the first two [numbers] on this sheet, and then you show me the next three, okay?” After these instructions, the child put on their earphones and the researcher demonstrated the task with the first two numbers. Then the child was prompted to do the three practice trials. During the three practice trials, the child was reminded of the rules as many times as necessary for them to comply with the instructions. It was not necessary for the child to correctly name each number to complete each trial.

Once the three practice numbers were successfully completed the child was given instructions to continue for the remainder of the worksheet. Once the worksheet was completed the child was given general praise for their effort and guided into the next activity.

Counting training. The second task of the instructional session was aimed at counting. By rolling the six-sided colour-sided die the child randomly selected a counting worksheet for the session (Figure 5). Each colour matched an A4 worksheet, except for red which was “roll again.” At the start of this task the child was given the following instructions:

“Now we’re going to change the game a little bit. This time the tape is going to tell you numbers. When it tells you a number, you tell me what the next two numbers are. Then, the tape is going to tell you what the right numbers are and you can see if you got it right. Then say the numbers the [voice on the] tape said. What you want to do is beat the tape and say the next two numbers before you hear them. Let’s do five practice ones okay? Are you ready?”

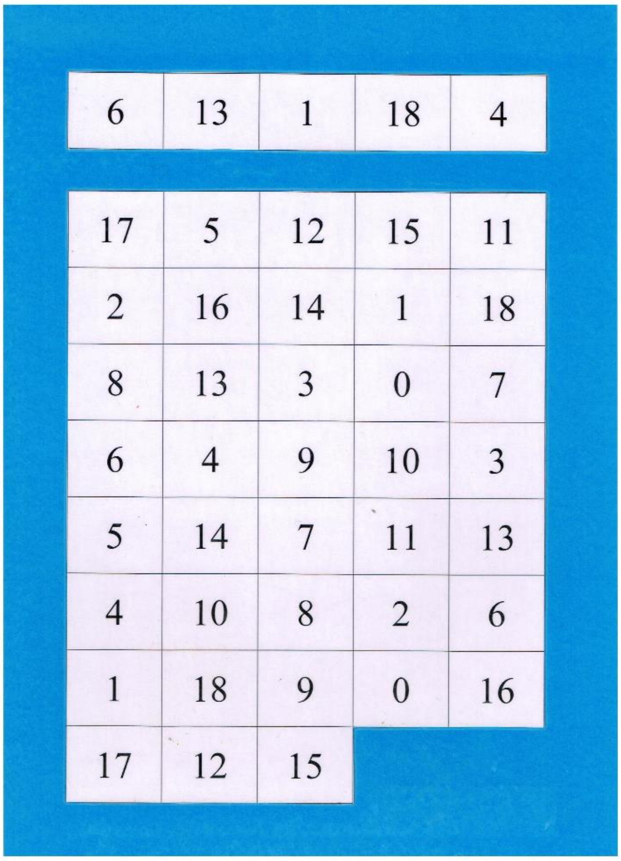


Figure 5. An example of a counting worksheet.

After each practice trial the child was reminded of any instructions they failed to follow.

Inhibitory control training. The third task in each session was designed to boost inhibitory control. At the beginning of this part the child was asked to remove their earphones and given the following instructions:

"Now we're going to play a game that's a little bit different. Here we have a small rod called a dowel. I'm going to tap the dowel on the table either once or twice and then put it in the middle of the table. Then you take the dowel and if I've tapped once, you tap it twice. If I tap it twice, you tap it once. Any questions?"

Thirty trials were run in the training component. If the child did not tap once when the researcher tapped twice, or tap twice when the researcher tapped once they were reminded of the instructions: "Remember, when I tap once, you tap twice. If I tap twice, you tap once." Then the experimenter gave the child the dowel and the child responded. The experimenter then said, "Good work, let's keep playing."

Immediately after the inhibitory control training, the measure of inhibitory control was made as described above.

Once the child had returned to the classroom activities, scoring procedures were implemented, data were recorded on a data collection sheet and the voice recordings deleted to clear space.

Follow-up Phase. Procedures during the follow-up phase were the same as the baseline phase and followed on immediately from the intervention sessions in the same, three per week, timeframe. Each child had 6 follow-up sessions. At the end of the final session children were thanked for their participation and given a certificate of their favourite cartoon character with their name on it. Each child was then offered their earphones to take home.

Data Analysis Plan

The data was graphed and visually analysed. Using Microsoft Excel®, data was displayed in a line graph by child and dependent variable. The graphs were then visually analysed for a noticeable difference in level, trend or variability between the baseline and intervention phases as these are necessary conditions for attributing an effect to the intervention (Blampied, 2001; Cooper, Herron & Heward, 1987). The follow-up phase was analysed to see if any changes occurring during the intervention phase were maintained.

To further analyse the data in this study, a single-case Effect Size measure was calculated for each child. For this, the nonoverlap technique Extended Celeration Line (ECL) was used (Parker, Vannest & Davis, 2011). This technique plots a least squares trend line through the baseline phase which is extrapolated through the intervention phase. The measure of effect is the proportion of points above and below the extrapolated trendline in the intervention phase. The percent of intervention phase data points that fall above the extrapolated baseline is called the percentage nonoverlap (Parker et al., 2011). If the intervention had no effect then it would be expected that half the data points in the intervention phase would lie above the extrapolated baseline and half below which would result in a percentage nonoverlap of 50%, so the effect of the intervention has to exceed 50% for a positive effect to be noted.

Chapter 4

Results

All participants completed the planned number of sessions. Each participant also had some sessions rescheduled in each phase due to absence as shown in Table 3.

Table 3

Number of Sessions that Were Rescheduled for Each Participant Within Each Phase.

	Baseline	Intervention	Follow-up	Total
Charlie	3	3	0	6
Drew	3	5	0	8
Sam	2	3	1	6
Yvette	1	9	0	10
Alex	10	2	4	16
Harri	3	4	4	11

To identify potential external events that might impact on participant performance during the study, teachers who had at least one participant in their class kept a record of the timing of any such events. Charlie, Drew, Sam and Harri's teacher reported the placement of a large number line on the classroom wall under the whiteboard where most of the teaching occurred between Charlie's session 9 and 10, Drew's session 9 and 10, Sam's session 8 and 9 and Harri's session 8 and 9. During the follow-up phase, between Charlie's session 18 and 19, Drew's session 17 and 18, Sam's session 19 and 20 and Harri's session 17 and 18, the number line was moved to above the front window.

Overall, the results for counting indicated that at baseline, five of the children were counting accurately to a number between 10 and 15 and the sixth child was counting to 20 (Figure 6). Four children had a flat and stable baseline for counting. The other two children had a decreasing baseline, one which was stable and the other which showed some variability. By the end of the of the Taped Numbers and Feedback phase four children were counting to 20, including the child who could count to twenty at the beginning of the study. The remaining two children did not improve in their counting. ECL analysis indicated that the percent non-overlapping data were 100% for four participants and 50% for the other participant. Gains for the children who were counting to twenty by the end of the Taped Numbers and Feedback phase were maintained throughout the follow-up phase.

The results for number identification indicated that at the beginning of the study, four children were verbally recognizing approximately 10 numbers between 0 and 20, another child was recognizing one, and the sixth child was recognizing approximately 15 (Figure 7). All children had a stable baseline of which three were flat and three were increasing slightly. By the end of the Taped Numbers and Feedback phase, three children were verbally recognizing all numbers up to 20, two children were still identifying at their baseline level of between five and ten and the sixth child had increased to recognizing between three and six. ECL analysis indicated that the percent non-overlapping data were 100% for four participants and 60% and 70% for the other two participants. The four children who made gains during the Taped Numbers and Feedback phase maintained their gains during the follow-up phase.

The results for inhibitory control indicated that at the beginning of the study, one child was correctly responding to all sixteen tapping trials, three children were making eight or nine of their tapping responses correctly out of sixteen trials and two children were making correct tapping responses on four of the sixteen trials (Figure 8). Five of the children had stable baselines of which two were flat, two were increasing and one was decreasing. The remaining child had a variable and decreasing baseline. Following the Taped Numbers and Feedback phase, all children were correctly responding to about 14/16 trials (87.5%). ECL analysis indicated that the percent non-overlapping data were all greater than 90% except for Drew’s which was 80%. Participant gains made by all children were maintained for the duration of the follow-up phase.

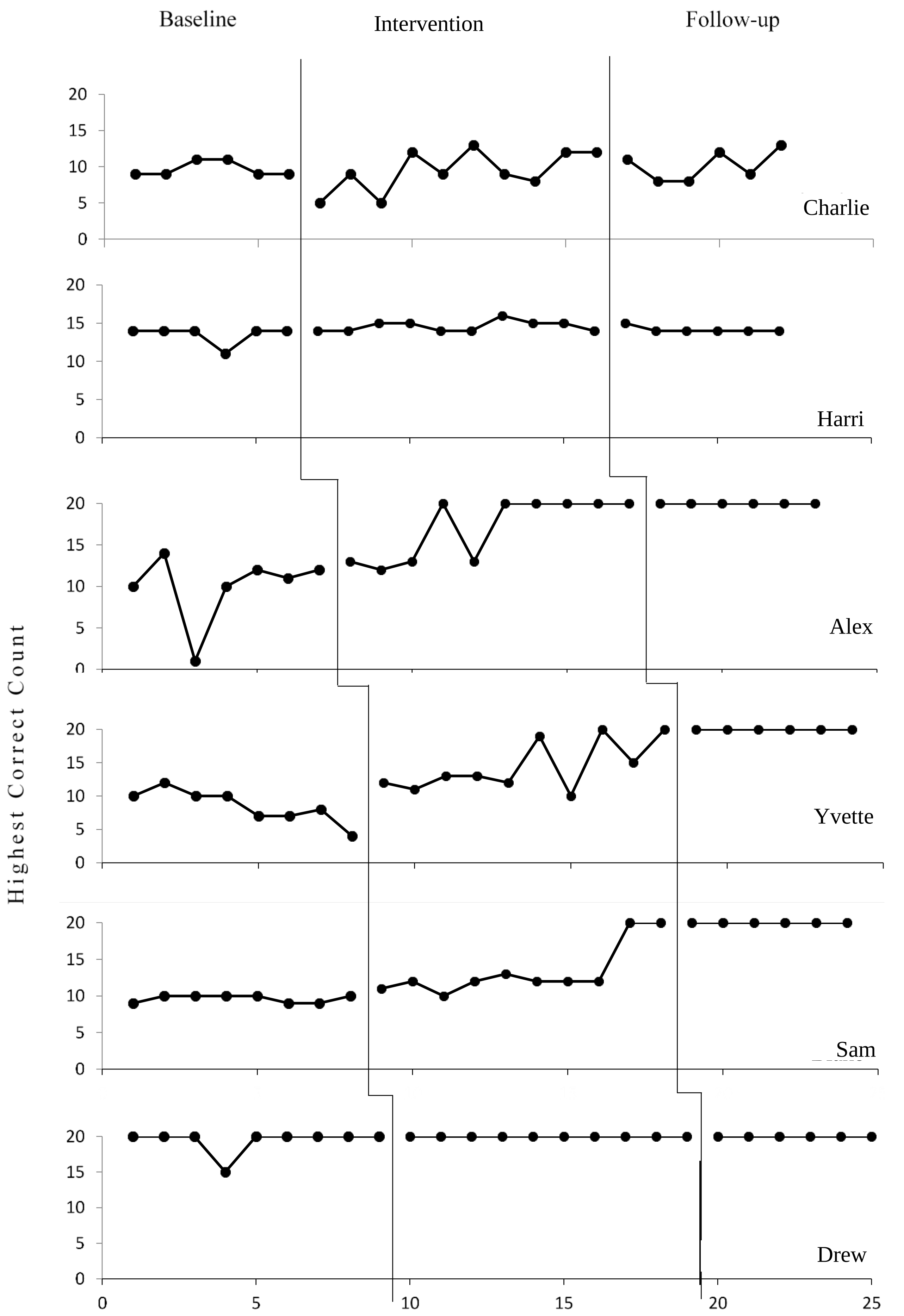


Figure 6. Participants’ highest correct count in the baseline phase (left), intervention phase (middle) and follow-up phase (right).

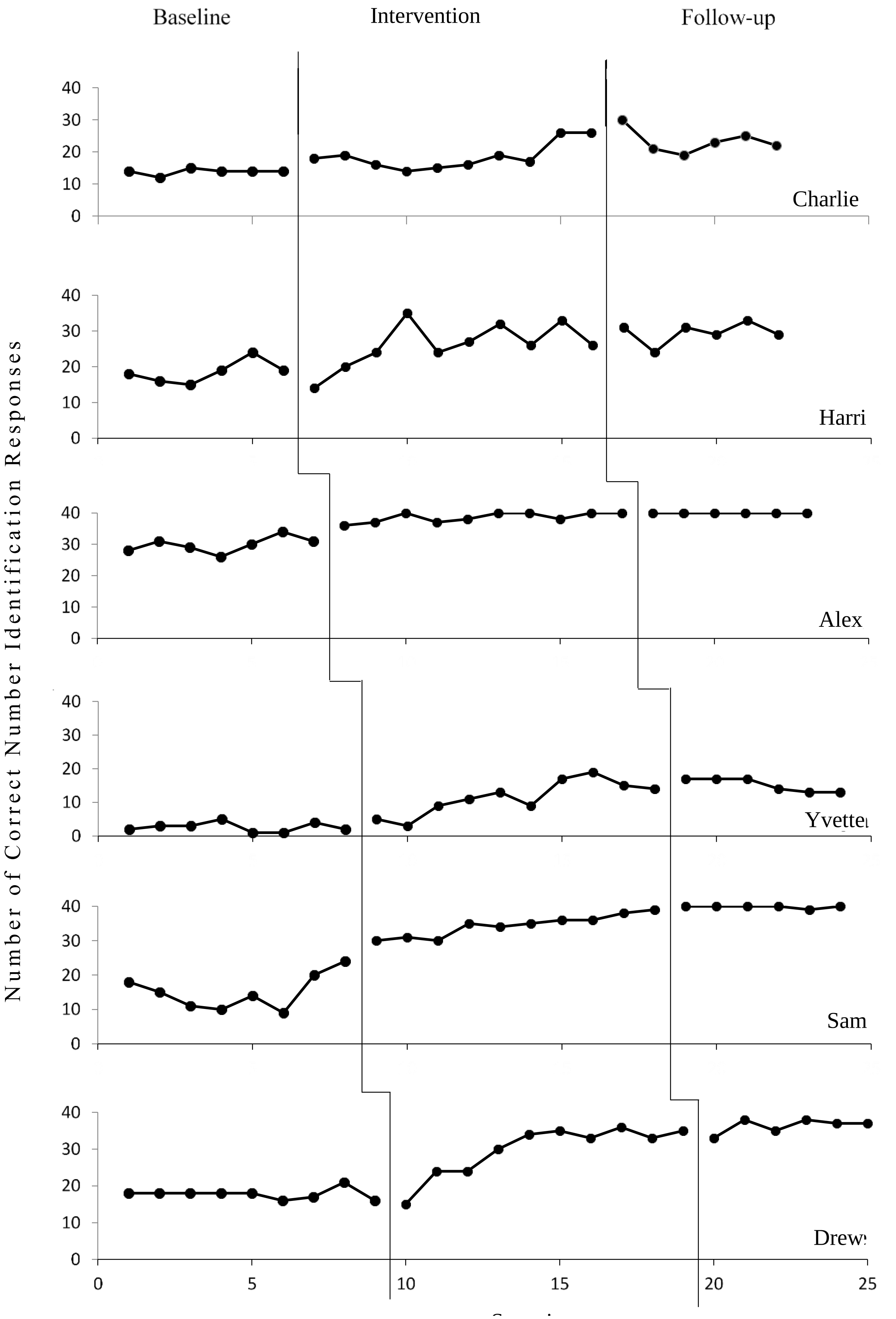


Figure 7. Participants' number of correct number identification responses in the baseline phase (left), intervention phase (middle) and follow-up phase (right).

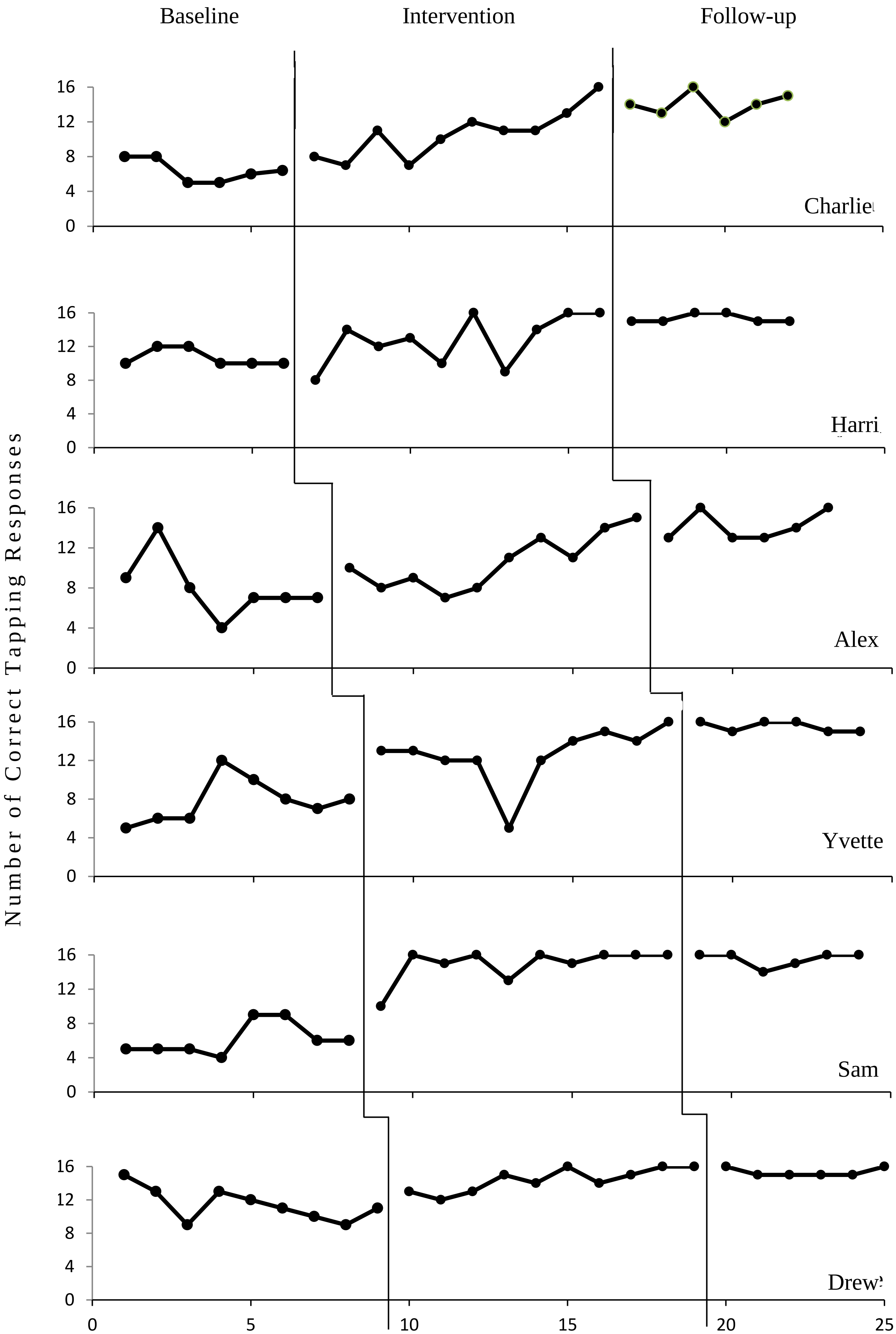


Figure 8. Participants' correct tapping responses in the baseline phase (left), intervention phase (middle) and follow-up phase (right).

Graphs were constructed to compare the change in counting, number identification and inhibitory control of each participant. The results for Charlie indicated the trend for counting was flat and stable during baseline and, after an immediate drop in counting from 9 to 4, was slightly increasing and variable during the Taped Numbers and Feedback phase (Figure 9). The percentage nonoverlap for counting is 60%. The trend for number identification was flat and stable in baseline and increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for number identification is 100%. The trend for inhibitory control was decreasing and stable in the baseline phase and increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for inhibitory control is 100%.The follow-up phase showed that skill levels in number identification and inhibitory control were maintained.

Drew's trend for counting was flat and stable during baseline and the Taped Numbers and Feedback phase (Figure 10). The percentage nonoverlap for counting is 100%. The trend for number identification was increasing and stable in baseline and the Taped Numbers and Feedback phase. The percentage nonoverlap for number identification is 50%. The trend for inhibitory control was flat and stable in the baseline phase and increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for inhibitory control is 80%. The follow-up phase showed that skill levels in number identification and inhibitory control were maintained.

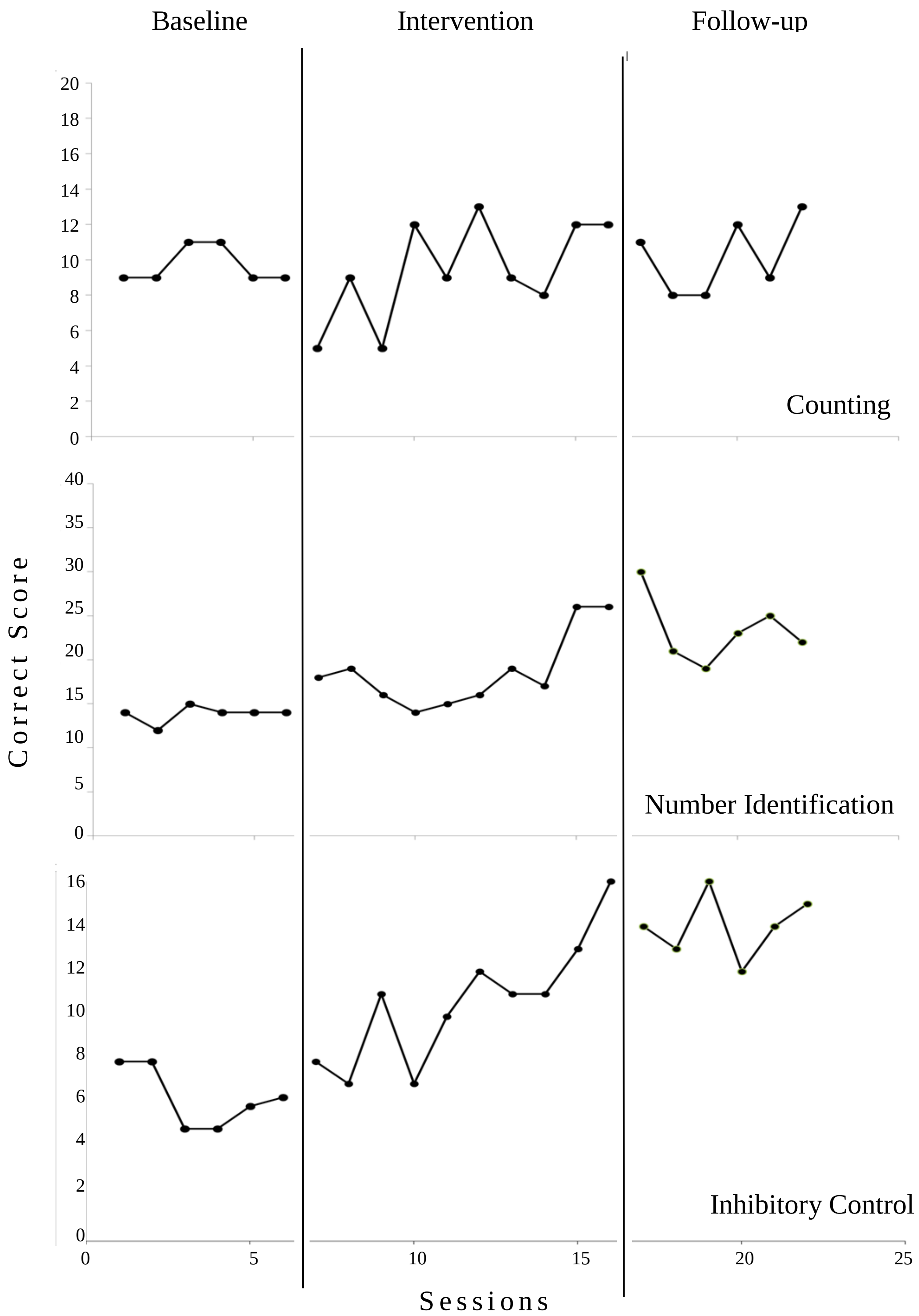


Figure 9. *Charlie's scores on counting (top graph), number identification (middle graph) and inhibitory control (bottom graph) across the experimental phases.*

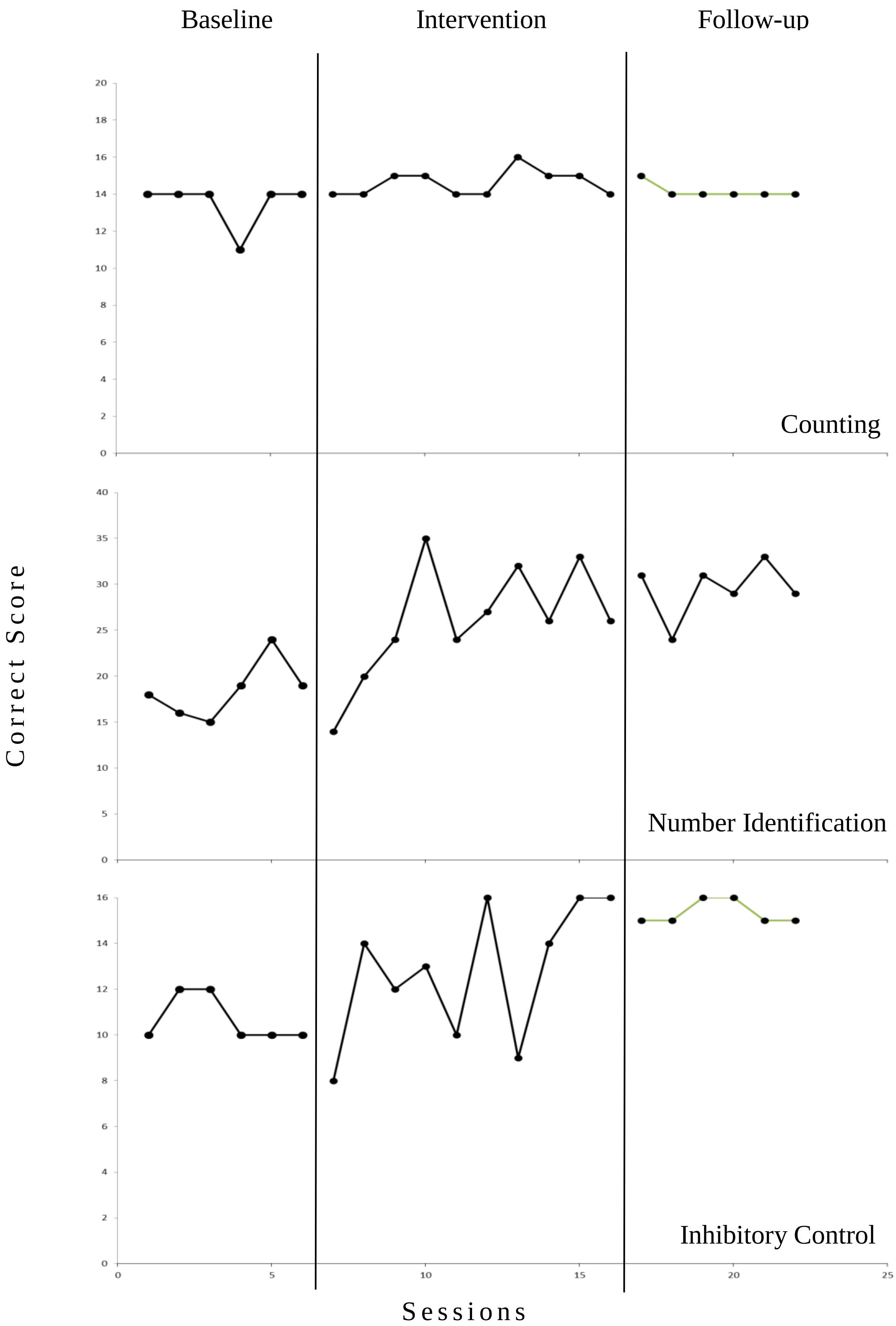


Figure 10. Drew's scores on counting (top graph), number identification (middle graph) and inhibitory control (bottom graph) across the experimental phases.

Sam's trend for counting was flat and moderately variable during baseline and was increasing and stable during the Taped Numbers and Feedback phase (Figure 11). The percentage nonoverlap for counting is 70%. The trend for number identification was slightly increasing and stable in baseline and the Taped Numbers and Feedback phase. The percentage nonoverlap for number identification is 100%. The trend for inhibitory control was decreasing and moderately variable in the baseline phase and increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for inhibitory control is 100%. The follow-up phase showed that all skill levels were maintained.

Yvette's trend for counting was decreasing and stable during baseline and, after an immediate increase in counting from 4 to 12, was increasing and variable during the Taped Numbers and Feedback phase (Figure 12). The percentage nonoverlap for counting is 100%. The trend for number identification was flat and stable in baseline and increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for number identification is 100%. The trend for inhibitory control was slightly increasing and moderately variable in the baseline phase and, after an immediate effect of 6 more correct tapping responses, was stable and continued increasing during the Taped Numbers and Feedback phase. The percentage nonoverlap for inhibitory control is 90%. The follow-up phase showed that all skill levels were maintained.

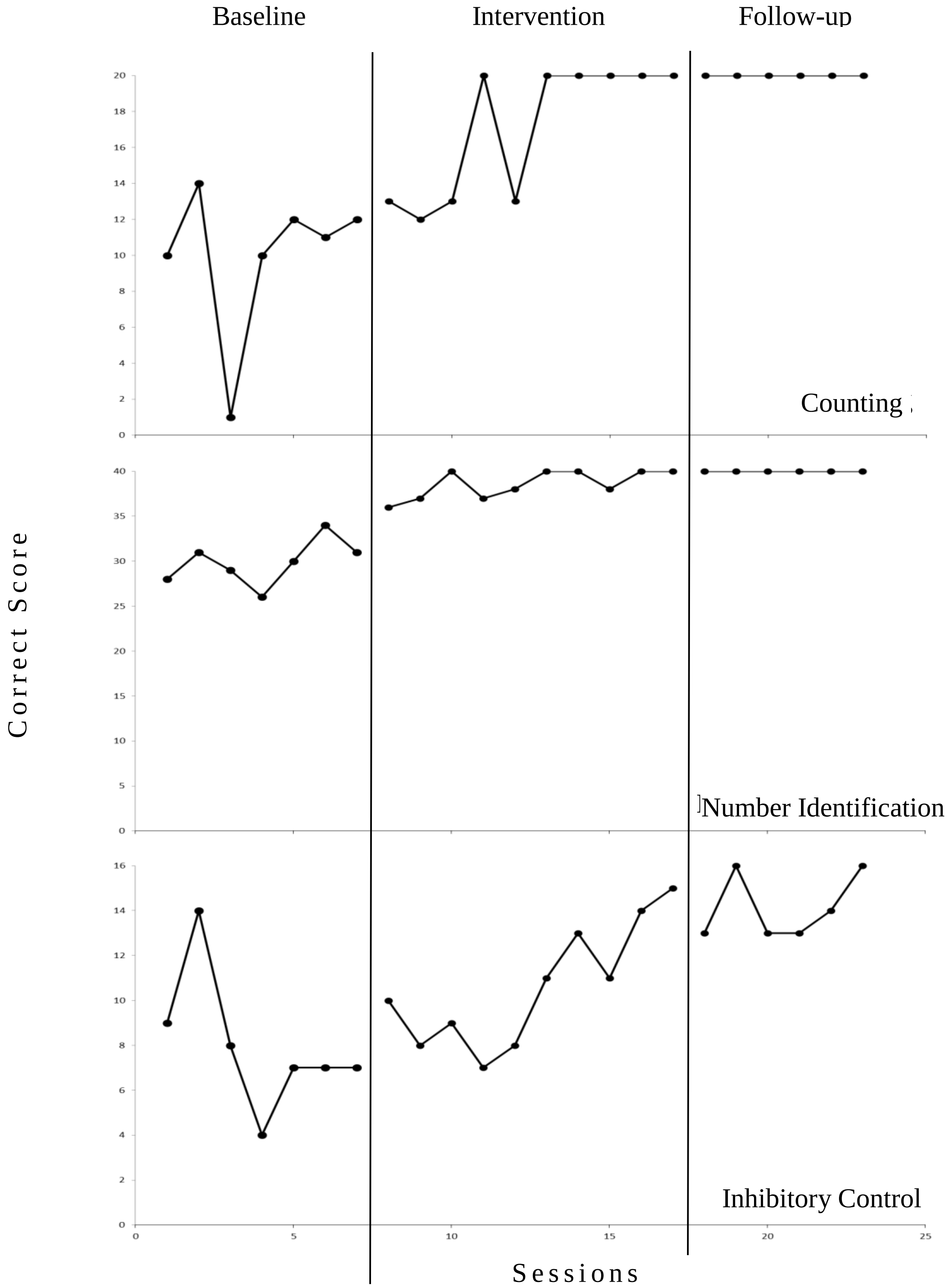


Figure 11. *Sam's scores on counting (top graph), number identification (middle graph) and inhibitory control (bottom graph) across the experimental phases.*

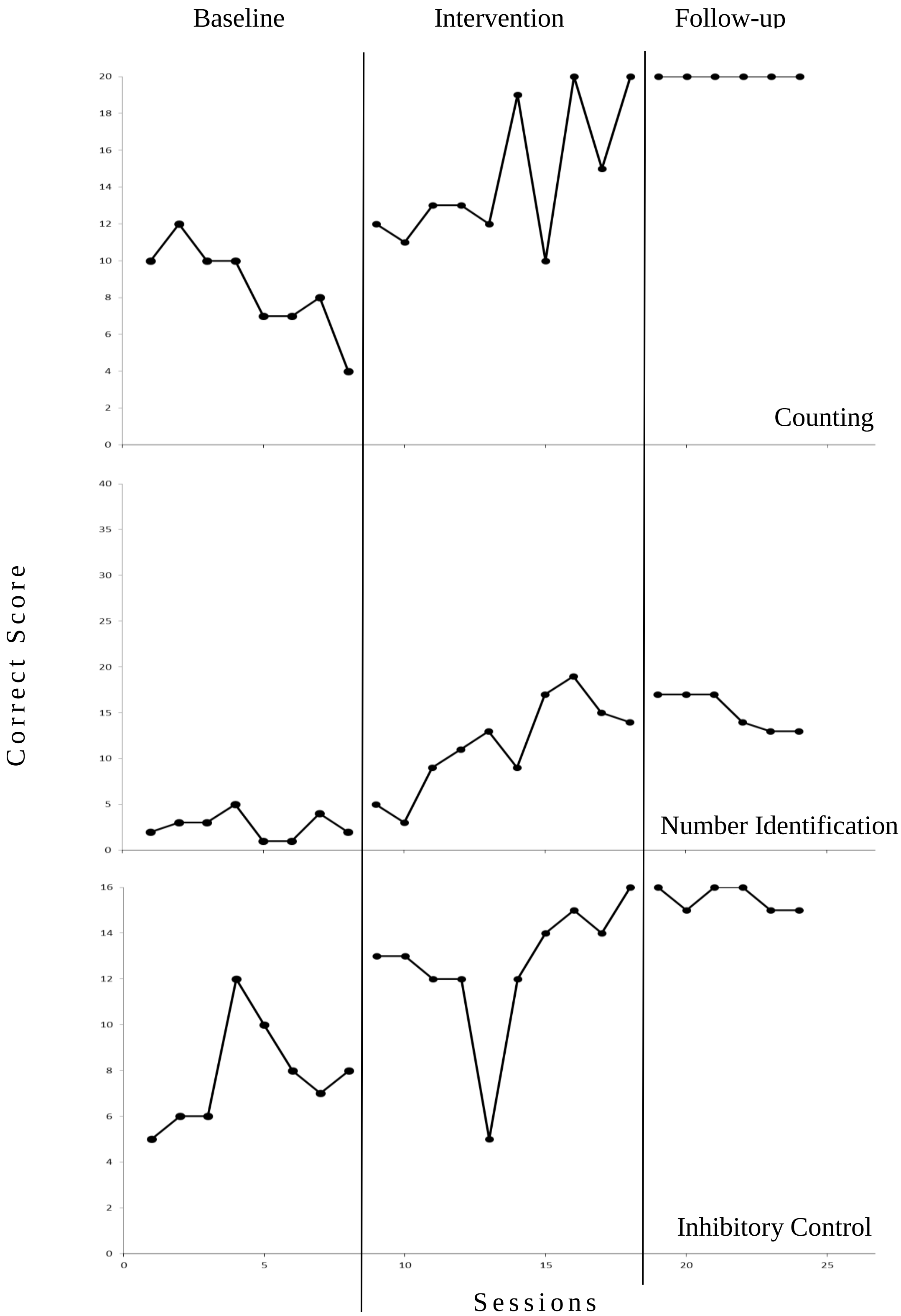


Figure 12. Yvette's scores on counting (top graph), number identification (middle graph) and inhibitory control (bottom graph) across the experimental phases.

Alex's trend for counting was flat and stable during baseline and was increasing and stable during the Taped Numbers and Feedback phase (Figure 13). The percentage nonoverlap for counting is 100%. The trend for number identification was curvilinear and stable in baseline and, after an immediate increase of 5 correct identification responses, increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for number identification is 100%. The trend for inhibitory control was slightly increasing and moderately variable in the baseline phase and, after an immediate effect of 5 more correct tapping responses, was stable and continued to increase during the Taped Numbers and Feedback phase. The percentage nonoverlap for inhibitory control is 100%. The follow-up phase showed that all skill levels were maintained.

Harri's trend for counting was flat and stable during baseline and the Taped Numbers and Feedback phase (Figure 14). The percentage nonoverlap for counting is 100%. The trend for number identification was flat and stable in baseline and increasing and stable in the Taped Numbers and Feedback phase. The percentage nonoverlap for number identification is 100%. The trend for inhibitory control was decreasing and stable in the baseline phase and was stable and increasing during the Taped Numbers and Feedback phase. The percentage nonoverlap for inhibitory control is 100%.The follow-up phase showed that number identification and inhibitory control skill levels were maintained. Harri met the inclusion criteria for the study because his number identification score was 18.

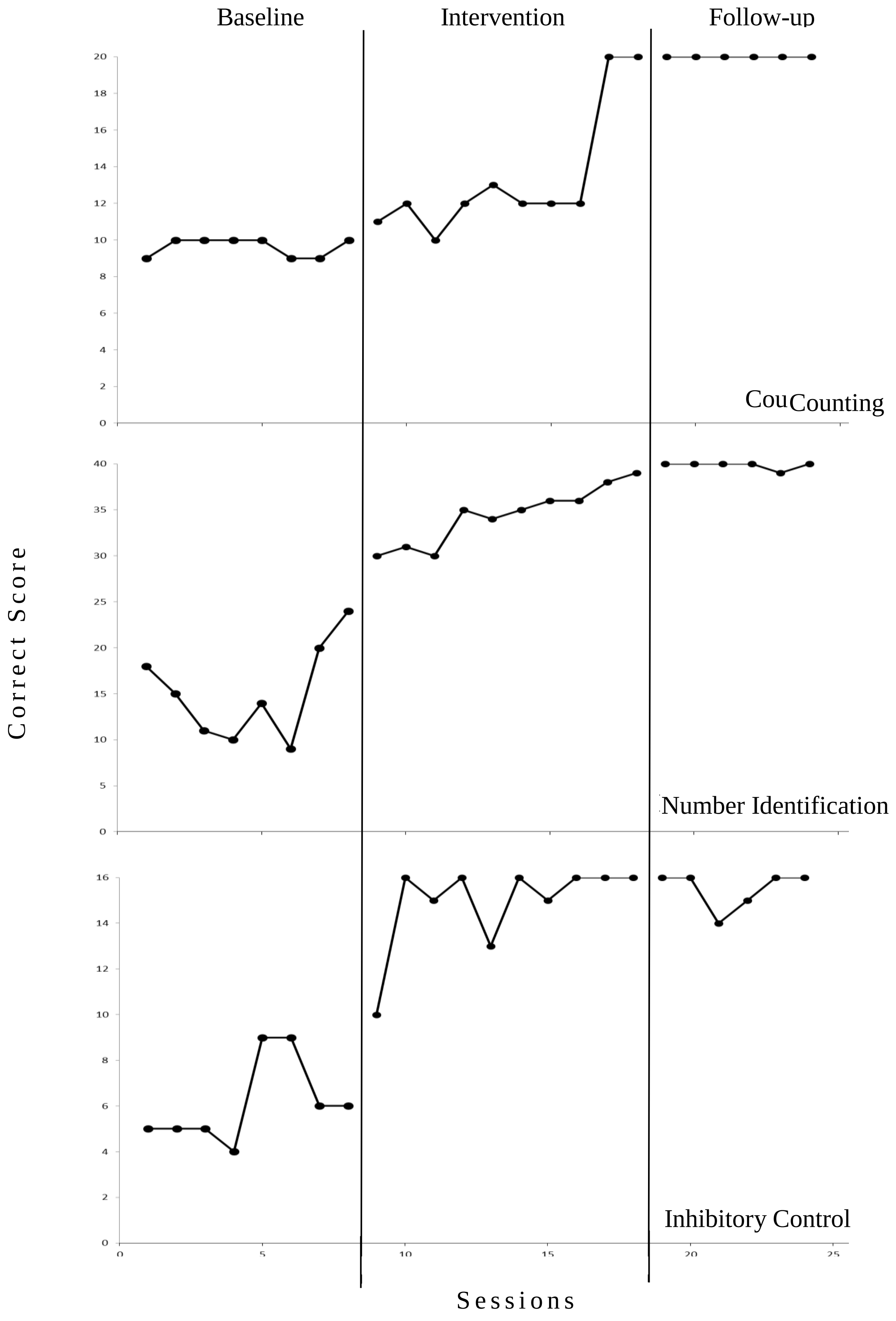


Figure 13. Alex's scores on counting (top graph), number identification (middle graph) and inhibitory control (bottom graph) across the experimental phases.

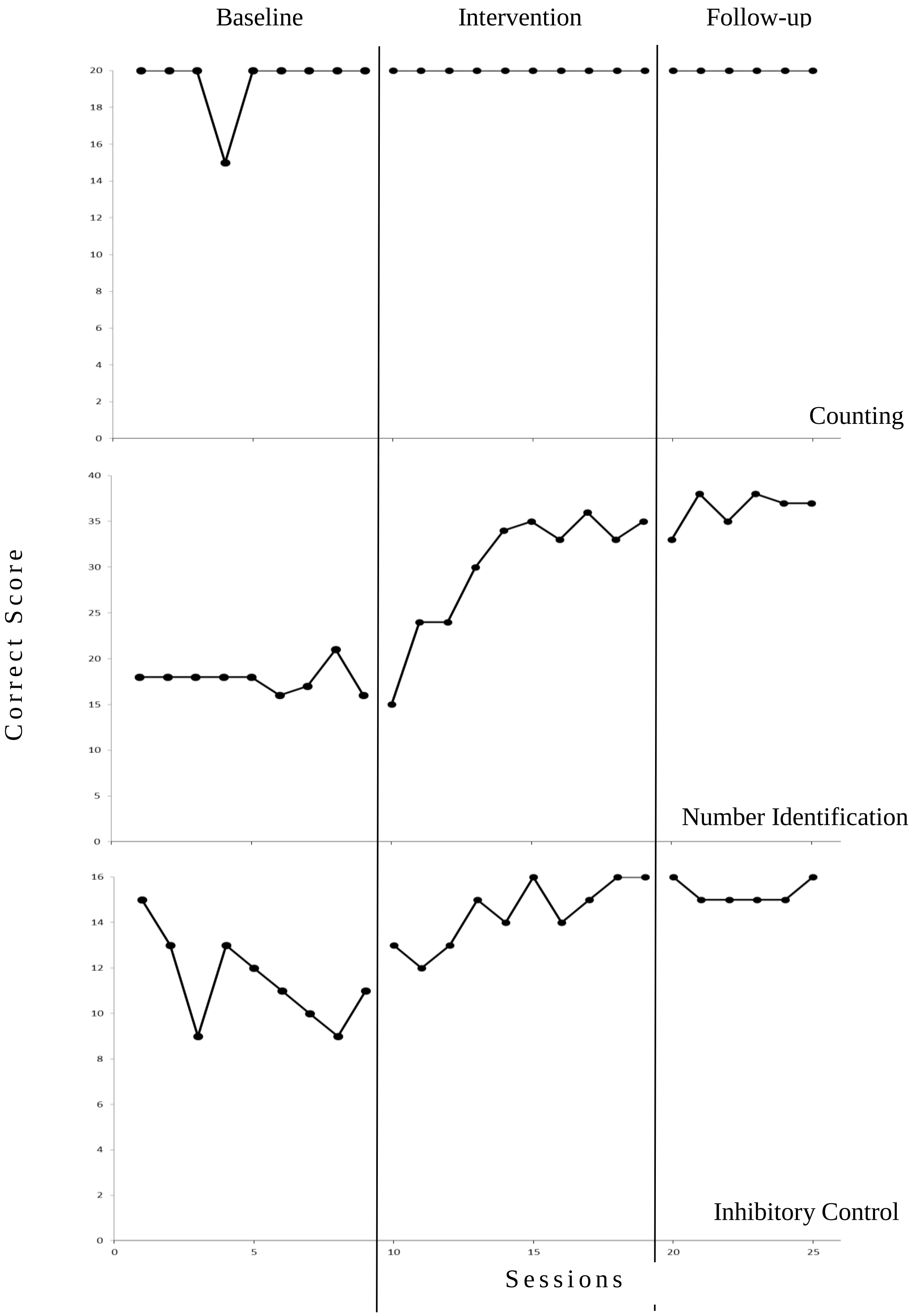


Figure 14. *Harri's scores on counting (top graph), number identification (middle graph) and inhibitory control (bottom graph) across the experimental phases.*

Chapter 5

Discussion

At the beginning of the intervention, five of the six children were counting at a level that might be improved by the Taped Numbers intervention (Harri was excluded from this summary as he began the study able to count to twenty). Of these, three were able to count to twenty by the end of the study. The other two participants remained at their baseline level of counting throughout the intervention. Three of the six children in the study were able to recognize all the numbers up to twenty by the end of the intervention and a fourth child made improvements from recognizing one number to recognizing five. ECL analysis of counting data showed large effect sizes for three children and a weak effect size for the other two (Parker et al., 2011). For number identification, ECL analysis showed large effect sizes for five of the six children but no effect on the number identification of the sixth child. The presence of unsuccessful replication of results for both counting and number identification indicates that Taped Numbers was a moderately effective intervention with low generalizability.

Accuracy on the motor inhibition task improved to over 85% for all participants as a result of the inhibitory control training. The ECL analysis showed strong effect sizes for all participants indicating that the inhibitory control training was highly effective (Parker et al., 2011). The theoretical framework for including inhibitory control training in the intervention was that it would contribute to the effectiveness of the counting and number identification training (Blair and Razza, 2007; Clark et al., 2010), however there is no evidence to support a relationship between gains on inhibitory control and gains on counting and number identification. Therefore, although the inhibitory control training was effective, there is no evidence to support the conclusion that it was effective as a catalyst for learning counting and number identification.

Comparisons

In the present study the participants improved from counting to 10 to counting to 20. These gains are greater than gains in counting made in any of the studies identified in the literature search. For example, in the study by Whyte and Bull (2008), sixteen preschool children made an average improvement from counting to seven to counting to 11. In the study by Dyson et al. (2011) fifty-five participants made an average improvement from counting to five to counting to six. In the study by Arnold et al. (2002), 112 children made a mean gain in counting from 13 to counting to 18. The 42 participants in the study by Jordan et al. (2012) made mean improvements from counting to six to counting to eight. In the study by Ramani et al. (2012), 54 participants made no mean improvements in counting.

In the present study, the participants improved from identifying 10 numerals to identifying 20. These gains are greater than those made in number identification in any of the studies identified in the literature search. For example, in the study by Krohn et al. (2012) four kindergarten children made an average improvement from identifying 5 numerals to identifying 10 numerals. The 16 participants in Whyte and Bull (2008) improved from correctly identifying four numbers to correctly identifying eight numbers. The 55 participants in Dyson et al. (2011) made a mean improvement from correctly identifying three numbers to correctly identifying six numbers. The 30 participants in Seigler and Ramani (2009) made a mean improvement from correctly identifying six numbers to correctly identifying seven numbers. The 42 participants in Jordan et al. (2012) who made a mean improvement from correctly identifying two numbers to correctly identifying six numbers. And the 54 participants in Ramani et al. (2012) made a mean improvement from correctly identifying six numbers to correctly identifying seven numbers.

Inhibitory Control

A potential contributor to the greater gains by participants in the present study as compared with participants in other studies identified in the literature search is the training in inhibitory control which was not provided in any other study. Although the present study found no temporal relationship between gains in inhibitory control and gains in either counting or number identification, the strong correlations between inhibitory control and mathematics suggest that gains in inhibitory control may improve the acquisition of mathematics skills including counting and number identification (Blair and Razza, 2007; Bull and Scerif, 2010; Clark et al., 2013; Espy et al., 2004; Kroesbergen et al., 2009). Furthermore, evidence indicates that executive functions including inhibitory control develop alongside mathematics through a dynamic and bidirectional relationship which suggests that training in one should catalyse training in the other (Welsh et al., 2010; Van der Ven et al., 2012).

Feedback

A possible contributing factor that led children in the present study to make greater gains than those in any other study identified in the literature search is because the intervention employed feedback on the task unlike the studies by Whyte and Bull (2008) and Dyson et al. (2011). Feedback on the task is the process through which an individual is given task-specific information regarding their response to the task such that they can improve their performance on their next attempt at the task. Feedback on the task has been shown to be a highly effective instructional approach (Hattie, 2009; Kluger & DeNisi, 1996). It is important to distinguish between providing feedback on the correctness of a response, which is ineffective, and providing feedback regarding the nature of the difference between the child's response and the correct response, which is highly effective (Hattie, 2009; Hattie & Timperley, 2007; Kluger & DeNisi, 1996). Video, audio or computer-assisted feedback show the greatest effects (Baker et al., 2002), although the greatest contributor to the effectiveness of feedback is the extent to which children can act upon the feedback. The present study utilized audio feedback in both the counting and number identification components of Taped Numbers and provided immediate opportunity for children to apply the feedback through the opportunity to use the correct response. For the counting component of Taped Numbers a tone signalled the participants to make an attempt at verbalizing the two numbers in numerical sequence that followed the number on the worksheet, after two seconds the voice on the audio tape would provide the correct response which the participant would then verbally repeat. For the number identification component of Taped Numbers a tone signalled the participants to make an attempt at verbally identifying the name for the numeral on the worksheet, after one second the voice on the audio tape would provide the correct response which the participant would then verbally repeat. In both components the child was given automatic feedback which they had the opportunity to apply immediately.

Relationship Building

A reason for the greater gains in the present study may be the greater time spent developing a relationship with the children prior to the intervention. A positive relationship between instructor and child plays a substantial role in the effectiveness of an intervention (Cornelius-White, 2007; Hattie, 2009). In fact, mathematics has the second highest correlation to positive instructor-student relationship of all academic subjects (Cornelius-White, 2007). In the present study the researcher conducted between six and nine baseline sessions with each child which included the researcher and the child playing Humpty Dumpty's Wall Game for approximately 15 minutes per session. During the game the researcher and each child became familiar with each other and developed a strong positive relationship. In contrast, no opportunity to build a positive relationship was provided outside of the administration of the measures and the intervention in Dyson et al. (2011), Siegler and

Ramani (2009) and Ramani et al. (2012). In each of these studies, the researcher had no allocated time to form a relationship with the children and the only contact with the participants prior to the intervention was the administration of pretest measures. Given the strong evidence to indicate that a positive relationship between an instructor and a child contributes substantially to the effectiveness of an intervention, the time dedicated to developing such a relationship in the present study may help explain the greater effects compared to those in Dyson et al. (2011), Siegler and Ramani (2009) and Ramani et al. (2012) which provided no time exclusively to the development of a positive instructor-child relationship.

Individual vs Small group Instruction

Children in the present study also made greater gains in both counting and number identification than participants in any of the studies identified in the literature search despite instruction occurring individually as opposed to the interventions in Krohn et al. (2012), Whyte and Bull (2008), Dyson et al. (2011), Seigler and Ramani (2011), and Ramani et al. (2012) which were conducted groups of approximately four children. Small group instruction is typically more effective than individual instruction, particularly in mathematics (Hattie, 2009). In fact, individual instruction has been shown to be no more effective for teaching mathematics than whole-classroom approaches (Horak, 1981). The reason that children in the present study made greater gains in both counting and number identification than those in the studies by Krohn et al. (2012), Whyte and Bull (2008), Dyson et al. (2011), Seigler and Ramani (2011), and Ramani et al. (2012) may be that the effects of including inhibitory control training, feedback on the task and a strong child-instructor relationship compensated for the less effective group size for mathematics instruction.

Total Instruction Time

An additional contributing factor that may help explain why children in the present study made greater gains in counting and number identification than participants in Krohn et al. (2012), Whyte and Bull (2008), Sielger and Ramani (2009) and (Ramani et al., 2012) is that they received more total instruction time. Participants in the present study received 3 hours and 20 minutes instructional time as compared to participants in Krohn et al. (2012) who received one hour and 15 minutes, participants in Whyte and Bull (2008) who received 2 hours, participants in Siegler and Ramani (2009) who received one hour and 40 minutes and participants in Ramani et al. (2012) who received total instruction time of one hour and 40 minutes. Evidence indicates that longer instruction time is related to greater gains although the effects are small compared with the other factors such as positive instructor-child relationship, feedback, and inhibitory control (Baker, Fabrega, Galindo & Mishook, 2004). Not only did participants in the present study make greater gains than children who received less instructional time, they also made greater gains than children who received greater instructional time. For example, children in the current study made greater gains in both counting and number identification than participants in Dyson et al. (2011) who received 12 hours of instruction, Jordan et al. (2012) who received 12 hours of instruction time and Arnold et al. (2002) who received a session of varying length every day for six weeks.

Three of the studies identified in the literature search did not provide sufficient data for a comparison of results. In the studies by Toll and Van Luit (2012), Young-Loveridge (2004) and Warren and DeVries (2009), children made gains on a general numeracy measure but data for individual components of numeracy such as counting and number identification were not reported despite these being subgroups within their respective measures of numeracy. The limited detail in these studies regarding how their reported gains were partitioned across the subcomponents of their measure makes comparison of effectiveness difficult. In contrast, the present study measured counting and number identification directly to allow for a more detailed understanding of intervention effects.

Additionally, in the study by Seigler and Ramani (2009), thirty participants made no measureable gains in counting due to a ceiling effect. Therefore any comparison of gains in counting with their study would have been invalid.

Limitations

Although the present study was successful in a number of ways it also has several limitations which must be considered. One important limitation was that the study failed to include reliability checks. In particular, counting responses and inhibitory control responses could have been easily assessed for inter-rater reliability from the audio-recordings of each session. Reliability of the children's performances on the number identification measures would have presented a greater challenge, but could have been accomplished with a second observer. The lack of data on the reliability of the measures emphasises the need for caution in interpreting the effectiveness of the intervention strategy in the present study.

Although the present study showed greater gains than any other study identified in the literature, the effects of Taped Numbers on participant counting were only replicated across two of four participants. The effects of Taped Numbers on number identification was replicated in three out of five participants. Overall Taped Numbers is a moderately effective intervention for improving counting and number identification in children in their first year of school. The Feedback intervention showed strong effects that were replicated five times indicating that it is a highly effective intervention for training the inhibitory control of children in their first year of school. The difference in effectiveness between the Taped Numbers component of the intervention and the Feedback component may be the result of instructor-given feedback in the inhibitory control training and self-directed feedback in the Taped Numbers intervention.

The study was limited by ending the Taped Numbers instructional phase after a pre-set number of sessions. Tailoring or adapting the number of sessions based on participant skill learning may have produced better results. For example Sam reached a close to maximum score on both counting and number identification in approximately five intervention sessions. Conversely, Yvette made progress less rapidly and may have benefitted from a longer intervention phase. By adapting the length of the intervention to match each participants' rate of learning the intervention strategy would become more efficient whilst simultaneously ensuring that all children in the intervention obtain the maximum benefit from the procedure.

The failure to establish a relationship between training in inhibitory control and gains from the Taped Numbers intervention may be the result of differences in the type of inhibition required for the task. Although both tasks require the inhibition of prepotent responses (interference control), this construct can be conceptually reduced further into subtypes of inhibition (Nigg, 2000). Given the extremely limited research on training inhibitory control, it is possible that the difference in these types of inhibition prevent the generalizing of training in one type to another. The important subtypes of inhibition to consider here are cognitive inhibition and motor inhibition. Cognitive inhibition is the effortful deletion of information from working memory (Nigg, 2000) as theorized to be employed during counting tasks. Inhibition Feedback trained motor inhibition which is the suppression of motor responses, which are not stored in working memory (Nigg, 2000). These differences may be sufficient to prevent the generalization of gains in Inhibition Feedback to counting and number identification. If indeed the gains in motor inhibition did not generalize to cognitive inhibition then the effect of Inhibition Feedback on counting and number identification may be minimal at best.

The order in which the measures were taken during baseline was reversed during the intervention phase and then reverted to its original order during the follow-up phase. The order in which measures are taken may influence participant scores and should therefore remain consistent across the baseline and intervention phases. Fortunately, that gains made during the intervention phase were maintained suggests that the reordering of measures had limited impact on participant scores in this study.

A limitation to the generality of the study was that it did not include procedural variants adapted to either the bicultural or the multicultural context of Aotearoa/New Zealand society. There are disproportionate numbers of Māori and Pasifika children who are behind their peers in mathematics (Ministry of Education, 2008; NEMP; 2009), meaning that remedial maths education must take this into account as evidence strongly supports the conclusion that interventions that are not culturally sensitive are substantial less effective across a range of cultures than interventions which have been adapted for multi-cultural populations (Hāwera & Taylor, 2011). The present study was a single-case design that was intrinsically limited in its capacity to accommodate cultural diversity among the population of children that struggle with mathematics in Aotearoa/New Zealand.

Another limitation of the present study is that no measures of treatment fidelity were employed. Treatment Fidelity is the degree to which the procedures are adhered to consistently across sessions and individuals. Significant deviations in procedure threaten the validity of the data. To some extent the threat of low fidelity is reduced through the use of a single instructor for all children across all sessions. Regardless, the lack of fidelity measure reduces confidence that measures were applied uniformly.

An important limitation of the present study is that it did not measure social validity. Social validation is the process of ensuring that a research project is socially important or that the results are meaningful in terms of the everyday life of the individual. There are three important components of social validity for interventions: social acceptability of the goals of the intervention, social acceptability of the intervention procedures and the social value of any gains made as a result of the intervention (Bailey & Burch, 2002; Foster & Mash, 1999). The first consideration is that the goals of the study are shared by society. As the aim of the study was to improve counting and number identification in first year primary school children, a skill which is actively taught in schools around the world, this component of social validity was met. Even if the ends are desirable to society, the means have to be acceptable as well. This can be achieved by ensuring that the intervention procedures implemented in the study are acceptable to both the participants and the consumers of the research. Given that the intervention technique is brief, non-invasive and based on scientific theory, this aspect of social validity is likely to have been met, although no data were collected to confirm this. Lastly, it is important to be confident that the intervention will have positive effects that meet the needs of the consumers. To establish this, information regarding the perceived effectiveness of the intervention should have been obtained from the classroom teachers.

Although the present study had some limitations, it also had a number of strengths that warrant consideration. Firstly, by exploring the role of inhibitory control training in numeracy instruction, this study explored a research question that has been recommended by a number of researchers (Blair and Razza, 2007; Clark et al., 2010). Although this study failed to find evidence to support a relationship between gains in inhibitory control and counting and number identification, the findings provide a first look into the potential of incorporating inhibitory control training into mathematics education.

Unlike many of the studies in the literature review, the present study measured maintenance. As gains were maintained, there is strong evidence that the continued reinforcement of the material through the intervention strategy is not required for maintenance of gains. This is extremely important for interventions in practice as short term effects are rarely desirable and are typically inefficient. Furthermore, as both counting and number identification are foundational in developing more advanced mathematics, regression of gains in these domains would prevent new numeracy skills from being learned.

Another strength of the present study is that the use of a single-case research design controls for novelty effects. That is, at the onset of a study participants may either try harder to impress the experimenter, or be shy and unwilling to try tasks that appear difficult. This risk to the validity of the data is controlled for in single-case designs by the baseline phase which gives children an opportunity to become familiar with the researcher and the measures. Indeed this was particularly prevalent in participants' first encounter with the measure of inhibitory control which was considerably higher than the following baseline measures.

Implications

The results of this study suggest a number of potential implications for practice. Children beginning their first year of school might benefit from a brief screen on counting and number identification as teachers were only moderately effective in nominating children who might benefit from the intervention with three of the eleven children nominated achieving above the exclusion criteria. This would present an opportunity to deliver Taped Numbers, as it is a low cost low intensity intervention that has good effects for some children. This would help prevent children already behind when they begin school from falling further behind and act as a first intervention towards preventing the poor adult outcomes associated with poor numeracy in adulthood.

Given the greater effects typically found in group instruction compared with individualized instruction, particularly for teaching mathematics, the procedure should be modified into a small group intervention. The challenge is to maintain the high level of specific feedback provided to each child in the individualized approach whilst incorporating the benefits of small group instruction. Simply having the children perform the current intervention in small groups is not enough to gain the benefits of small group instruction (Hattie, 2009). To achieve this effect the children in the group need to be engaging in the task collectively. There are two points in the procedure wherein this might occur. The first is by increasing the delay between the tone prompt and the feedback such that all children in the small group have a chance to make the attempt before the correct answer is provided might be one approach. An alternative might be for one child to attempt each trial, with the child making the attempt being rotated across the group.

Changes in the procedure need to be applied to better accommodate the multicultural context of Aotearoa/New Zealand, for example the inclusion of Kaupapa Māori principles. A core foundation of Kaupapa Māori approaches to educational practices is rangatiratanga (self-determination; Bishop, 2003). Although this is ideally implemented at a curriculum planning level (Bishop, 2003), this can be applied to an educational intervention by giving children the opportunity to be involved in any decision making processes. For the present study this might include replacing the random selection of a worksheet through rolling the colour die through a diminishing choice pool such that all worksheets are completed but the order is chosen by the participant based on an arbitrary attribute of the worksheet such as a small design on the back or the worksheet's colour. Concurrently, including whānau in the intervention process would help to make the intervention more culturally sensitive (Bishop, 2003). This could be achieved by training whānau in the delivering of the intervention so that they can implement home-based sessions in coordination with school based sessions.

A possible reason that Inhibition Feedback was more effective than Taped Numbers is the difference in the delivery of the feedback. In the Taped Numbers component participants were delivered feedback through an audio file on an MP3 player. In contrast, feedback in the Inhibition Feedback component was delivered by the experimenter. As the child-instructor relationship has been shown to contribute to the effectiveness of an instructional strategy (Cornelius-White, 2007; Hattie, 2009), it is likely that feedback delivered by the experimenter was more effective. Future research should consider replacing the audio-tape delivery of feedback in Taped Numbers with experimenter delivered feedback instead to see if this component of Inhibition Feedback indeed explains why it was more effective than Taped Numbers.

To increase the efficiency of Taped Numbers, future research might consider integrating the counting and number identification components into a single worksheet. The procedure would then need to be readjusted so that for each numeral on the worksheet children were first required to identify the number and then count up from that number. Combining the counting and number identification components of Taped Numbers into a single worksheet would provide greater efficiency for the implementation of the intervention and may help children integrate the counting and number identification into a greater understanding of numeracy.

Future research should seek to develop our understanding of the relationship between inhibitory control and mathematics achievement. There are a large number of factors which would strengthen future attempts to incorporate inhibitory control into a mathematics intervention. Initially, a study should explore the relationship between different types of inhibition with different components of numeracy to provide a more detailed understanding of how inhibition and mathematics are related. This would provide the necessary information to develop an appropriate training technique to match the mathematics skills taught in an intervention.

Future research would do well to obtain data on the social validity of Taped Numbers and Inhibition Feedback. The acceptability of the goals of the intervention have been sufficiently justified, but data on both the acceptability of the intervention procedures and the value of the outcomes would be worthy of obtaining in future studies. Data on the acceptability of the intervention procedures can be obtained from the participants through a short 3-point likert scale questionnaire. Such a questionnaire would need to be worded in a developmentally appropriate manner and should include faces instead of numbers to indicate different degrees of satisfaction. Questions which might be useful to ask include "How much fun did you have doing the activities with [researcher name]?", "How happy were you with how long each session took?" and "Did you learn something from these sessions?" An effective way to obtain data on the value of the intervention outcomes is through a brief interview with the classroom teachers of children in the study. As such, future research should include a short questionnaire on the acceptability of the intervention procedures for the participants and a brief interview with participants' classroom teachers to determine the value of gains made.

Conclusion

This study marks an important first step in the integration of executive functions into interventions of early numeracy. The counting component was effective for three of five children and the number identification component was effective for four out of six children. Although the Inhibition Feedback was successful in improving inhibitory control in all six children, no temporal relationship could be established. A number of directions for future research may help to provide further evidence as to the role that inhibitory control training can play in teaching young children early numeracy.

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Appendices

Appendix A: Copy of Letter of Approval from the Ethics Committee

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: 2013/44/ERHEC

17 July 2013

Tom van Laanen
School of Health Sciences
UNIVERSITY OF CANTERBURY

Dear Tom

Thank you for providing the revised documents in support of your application to the Educational Research Human Ethics Committee. I am very pleased to inform you that your research proposal "The potential benefits of an early teaching strategy on counting, number identification and inhibitory control in new entrant children" has been granted ethical approval.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 12 July 2013.

Should circumstances relevant to this current application change you are required to reapply for ethical approval.

If you have any questions regarding this approval, please let me know.

We wish you well for your research.

Yours sincerely

Nicola Surtees
Chair
Educational Research Human Ethics Committee

"Please note that Ethical Approval and/or Clearance relates only to the ethical elements of the relationship between the researcher, research participants and other stakeholders. The granting of approval or clearance by the Ethical Clearance Committee should not be interpreted as comment on the methodology, legality, value or any other matters relating to this research."

E S

Appendix B: Teacher Diary Template

<table>
<tr><td colspan="2">Teacher Recording Sheet</td></tr>
<tr><td>Teacher Name:________________________</td><td>Participant Name:______________________</td></tr>
<tr><td colspan="2">Instructions: For the duration of your student’s participation in this study, you are asked to record an event which you believe may be having an impact, either positive or negative, on that child’s number identification skill, counting skill or inhibitory control. Please make a minimum of one entry each teaching day. If nothing unusual has contributed to these skills please note “None” in the event column.</td></tr>
<tr><td>Day</td><td>Event</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Monday</td><td></td></tr>
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